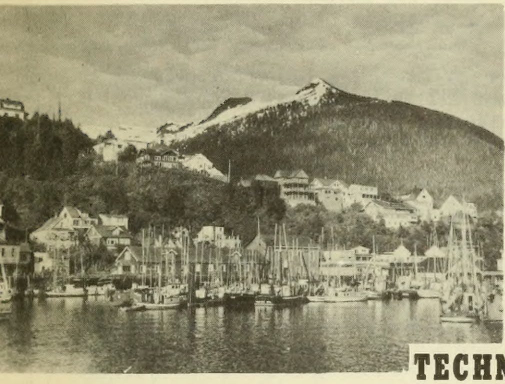
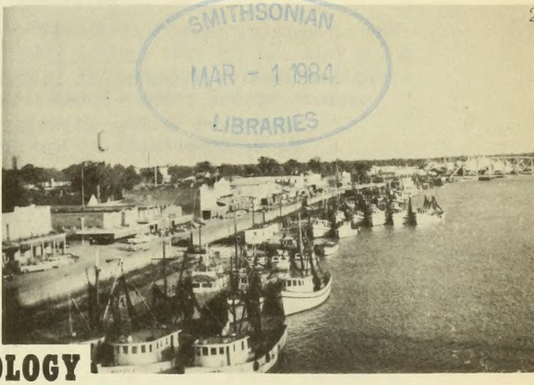
COMMERCIAL FISHERIES REVIEW





TECHNOLOGY SUPPLEMENT

Vol. 14, No. 12a **DECEMBER 1952 - SUPPLEMENT**

FISH and WILDLIFE SERVICE
United States Department of the Interior
Washington, D.C.

UNITED STATES
DEPARTMENT OF THE INTERIOR
OSCAR L. CHAPMAN, Secretary

FISH AND WILDLIFE SERVICE
ALBERT M. DAY, Director

COMMERCIAL FISHERIES REVIEW

A REVIEW OF DEVELOPMENTS AND NEWS OF THE FISHERY INDUSTRIES
PREPARED IN THE BRANCH OF COMMERCIAL FISHERIES

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Applications for COMMERCIAL FISHERIES REVIEW, which is mailed free to members of the fishery industries and allied interests, should be addressed to the Director, Fish and Wildlife Service, U. S. Department of the Interior, Washington 25, D.C.

The printing of this publication has been approved by the Director of the Bureau of the Budget, December 15, 1949.

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COMMERCIAL FISHERIES REVIEW

December 1952 Washington 25, D.C. Vol.14, No.12a

PROGRESS ON TECHNOLOGICAL RESEARCH PROJECTS OF THE SERVICE'S BRANCH OF COMMERCIAL FISHERIES, 1951-52

A discussion of the Fishery Technological Research Program appeared in the November 1951 Supplement of Commercial Fisheries Review, vol. 13, no. 11a, pp. 2-7 (also reprinted as Separate 294). A review of the progress made in each project during the fiscal year 1952 (July 1, 1951-June 30, 1952) follows:

NUTRITION

1. Investigation of the toughening of frozen blue-crab meat. Experimental work was conducted the previous year to determine if enzymes are involved in the change of texture of frozen crab meat. Some preliminary work was done to identify the enzyme or enzymes present in crab meat. This year, work on this project was stopped temporarily because no one was available to continue the research.

2. Feeding studies with gums extracted from Irish moss. Gums are being extracted from Irish moss and derivatives of these are being used in foods and pharmaceutical preparations. Rats and mice have been allotted to 5 comparable groups and fed a balanced ration to which has been added 0, 1, 5, 15, and 25 percent of the gum. The animals have now been on experiment from about 1 to 1½ years and will be kept on experiment until death. The data to the present time indicate that the product is wholesome.

3. Chemical and physical properties of fish and shellfish proteins. A fundamental study of water retentivity in meat of fish, with particular reference to the mechanism of drip formation in frozen fish, is being made. It was found that drip formed maximally at the time that the last vestige of frost disappeared. More drip was formed in thawing at high temperature than at low. Spoiled fish yielded more drip than did fresh fish. The amount of drip varied for different species of fish. Less drip resulted from fast freezing than from slow freezing. The initial effect of freezing rate of the fish on the amount of drip was nullified on subsequent storage of the frozen fish. The foregoing findings for fish applied also to oysters. Passing fresh fish through a food chopper having ½-inch holes reduced the water retentivity, or produced the same amount of drip as did freezing the fish.

4. Thiaminase content of certain species of fish used in feeding fur animals. Thiaminase, an enzyme occurring in some fish, destroys the vitamin thiamine. When this enzyme is present in high concentration in the diet, it causes a nutritional polyneuritis known as Chastek paralysis. Since large quantities of raw fish waste are used for feeding fur animals, the level of thiaminase activity in several samples of fish waste was determined. These samples included Alaskan salmon waste, and true cod, rockfish, and sole filleting waste. In the samples so far examined the level of thiaminase activity is very low.

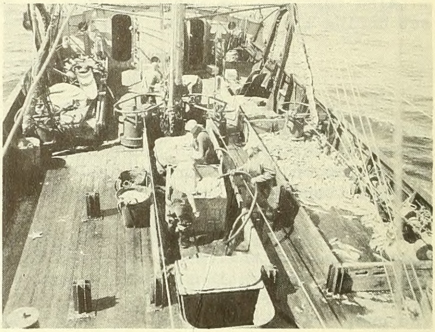
5. A study to determine the comparative hemopoietic value of fish. The previous year a metabolism study was conducted with the cooperation of the College of Home Economics of the University of Maryland. A group of 8 girls consumed a basal diet low in protein but adequate in vitamins, minerals, and calories. Four

girls received an additional allowance of protein in the form of fish, and the other four girls received theirs in the form of beef or veal. During a 6-week test period, there was no difference between the two groups in the composition of weekly samples of venous blood or the efficiency in which the protein of the fish or meat was utilized. Selected food samples are now being analyzed to determine how published values compare with actual values for iron, calories, and vitamin B_{12} of the foods used. This work will continue into the coming year.

REFRIGERATION

1. Freezing fish at sea, defrosting, filleting, and refreezing the fillets.

a. OVERHAUL OF THE RESEARCH TRAWLER DELAWARE AND THE FISHING OPERATIONS: The Delaware was completely overhauled and placed in good operating condition. Some of the major items completed were: thorough overhaul of the main engine and propulsion equipment; replacement of the trawl-winch Diesel engine, the towing gear, and the batteries; installation of echo-sounding equipment; and renovation of the crew's quarters.



ABOARD THE RESEARCH TRAWLER DELAWARE. HANDLING FISH FOR THE FREEZING-FISH-AT-SEA PROJECT.

The fishing and deck gear were thoroughly tested during the cruises completed. Minor changes and adjustments were made as required. Fishing was conducted in the Georges Bank area to supply fish for other phases of the project.

b. FREEZING AND STORING FISH ABOARD VESSEL: The refrigeration machinery, the brine-freezer system, and the refrigerated storage system (newly installed aboard the vessel) were tested in use under at-sea operating conditions. Based on this experience and observations, extensive alterations and improvements were made. A second refrigerated storage room, operating at 0° to 5° F., was installed in the fish hold.

Numerous lots of fish in the several size and species categories common to the New England banks were frozen in brine, stored aboard ship, and returned to the laboratory for continuance of the project's research.

c. DEFROSTING, FILLETING, AND PACKING OF FISH ASHORE: The round frozen fish from the Delaware were used to further test, on a large scale, the equipment and techniques developed in the pilot-plant ashore. The information thus obtained was prepared for use in recommending equipment and procedures for the thawing of round frozen fish by commercial concerns.

Several 1,000-pound lots of round brine-frozen fish were thawed in the pilot-plant equipment, filleted, and packaged by a commercial concern. The fillets were placed in a commercial cold storage for comparison at biweekly intervals over a six-month period, with fillets from iced, gutted fish similarly stored.

d. TASTE PANEL AND CHEMICAL TESTING OF FISH IN THE LABORATORY: Early in the project the laboratory staff tested round brine-frozen fish prepared aboard the Delaware from the standpoint of salt penetration. These tests showed that when brine freezing was accomplished within the normal expected operating temperature range for the Delaware, and when these frozen fish were thawed in fresh water, the residual salt content of the fillets was no more than that of fillets from iced, gutted fish.

The taste panel, to pass upon the palatability of the fish fillets prepared on the project, was set up and trained. Taste-panel tests are being used:

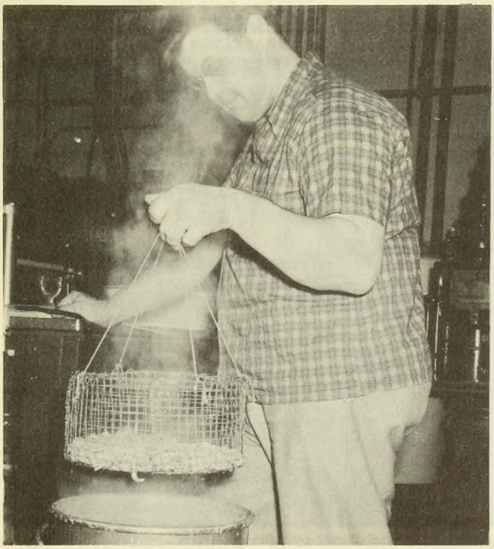
(1) To establish the normal palatability level of commercially-prepared frozen and fresh fillets obtained at random on the local retail market;

(2) To assist in the establishment of an optimum fillet-brining procedure; and

(3) To evaluate the series of stored frozen fillets for possible changes that may develop during their normal storage life.

Procedures for physical and chemical evaluation of the quality and other allied characteristics of fish products were tested for use as supplements to the taste-panel observations.

Results of tests on frozen fillets after about six months in storage indicate that no significant differences have developed in the fillets from round brine-frozen fish as compared to those from iced, gutted fish.



PRECOOKING ALASKA SHRIMP MEATS IN BRINE FOR STUDIES ON FREEZING AND STORING ALASKA SHRIMP.

In anticipation of improvements in the operation at sea, extensive testing has been conducted by the laboratory to develop freezing solutions or media both adaptable to temperatures in the -10° to -20° F. range and otherwise satisfactory for the freezing of round fish in existing vessel equipment.

2. Freezing and storing Alaska shrimp and dungeness crab. Preliminary work during 1950-51 indicated that development of adverse flavor and texture changes in frozen shrimp was affected by the methods of preparation of the shrimp for freezing. A series of sample packs of frozen Alaska shrimp were prepared early in 1952 using various processing and packaging procedures.

3. Preparation of a manual on the refrigeration of fish. Two chapters of the manual on the refrigeration of fish have been completed and are ready for review and editing.

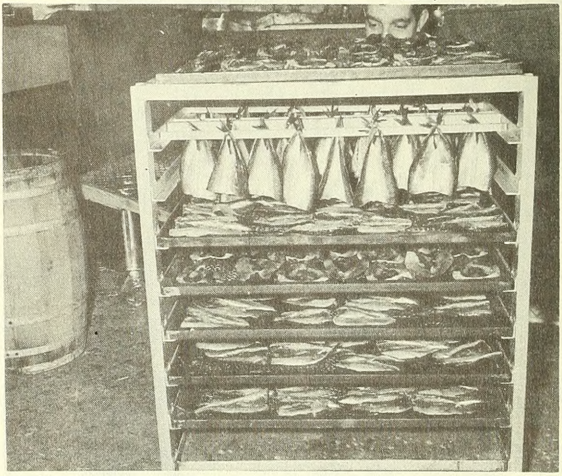
4. The effect of storage conditions on quality of frozen fish. Frozen whole fish, stored in refrigerated rooms provided with unit coolers employing blowers for circulation of air, will lose their protective ice glaze rapidily. The glaze protects the fish from dehydration and also delays the development of rancidity, particularly in the fatty fish. Tests with frozen glazed whole salmon using pilot-plant refrigerated storage (0° F.) facilities indicated that unprotected frozen salmon lost most of the ice-glaze after 4 weeks of storage, but salmon wrapped in heavy kraft paper or placed in fibre boxes lost most of the glaze only after 20 weeks of storage. Results to date on further tests in progress indicate that glazed frozen whole salmon wrapped in heavy waxed paper or in polyethylene bags lost no appreciable amount of ice-glaze after 6 months of storage at 0° F.

5. Study of cause of texture change of canned salmon prepared from frozen fish. Previous experiments indicated that freezing salmon prior to canning produces adverse changes in the final products. These changes are (1) toughening of the canned product, (2) excessive curd formation, and (3) absence of free oil. Further tests indicated that the length of frozen storage prior to canning is directly correlated to the adverse texture changes. Apparently, freezing salmon without subsequent storage causes no major texture change in the canned product, but subsequent storage induced toughening of the canned product.

It has been shown that brining can-sized chunks of the thawed salmon substantially reduces curd formation in the canned product.

PROCESSING AND PRESERVATION

1. Development of specialty food products from Alaska fish and edible fish trimmings. Several test-canned packs of plain and smoked salmon eggs, smoked herring, smoked clams, and smoked shrimp were prepared. Use was made of the newly-constructed controlled smokehouse installed at the Ketchikan laboratory. Several products showed definite promise as commercial canned specialty fish items.



PREPARING HERRING FOR SMOKING IN THE NEWLY-CONSTRUCTED CONTROLLED SMOKEHOUSE AT THE KETCHIKAN FISHERY PRODUCTS LABORATORY. PURPOSE WAS TO DEVELOP SPECIALTY FOOD PRODUCTS FROM ALASKA FISH.

ANALYSIS AND COMPOSITION

1. Chemical composition of fish: (1) Menhaden. An extensive review of the literature was made during the early part of the year in order to determine what chemical or pharmaceutical preparations had been reported to have been made from fishery products. A report entitled "Chemistry of Menhaden" was published in the November 1951 Technological

Supplement to Commercial Fisheries Review. Two articles dealing with products from menhaden were prepared and published in trade journals. Experimental work on this project is now held in abeyance in favor of working on the production of dried menhaden solubles.

2. Cooperative work with the Association of Official Agricultural Chemists. This project was set up on a part-time basis and work was scheduled for May, June, and July of 1952.

3. Composition and cold-storage life of fresh-water fish.

a. COMPOSITION: The proximate composition (moisture, oil, protein, and ash) of the edible portion and the fillet yield of 16 individual fish of 6 species (blue pike, yellow pike, yellow perch, whitefish, sheepshead, and smelt) were determined. The whitefish had a high oil content and showed considerable variation in the oil content from one fish to another. Sheepshead had a moderate amount of oil and showed some variation from one fish to another. The smelt had a low oil content and showed only small variation from fish to fish. All other species were relatively non-oily. Other components for all fish were fairly consistent.

b. COLD-STORAGE LIFE: Samples of the frozen fresh-water fish were also placed in cold storage to determine their keeping qualities at 0° F. Blue pike, yellow pike, and yellow perch showed no significant deterioration in quality after 6 months of storage. The frozen sheepshead were somewhat rancid on receipt at the laboratory. Subsequent storage of these fish showed only a slight decrease in quality after 6 months. The whitefish were quite soft on thawing and were difficult to fillet even at the initial examination; however, the cooked samples were rated good in flavor and texture. After 3 months of storage of the whitefish, there was no detectable change in quality. Samples of Lake Michigan smelt and Columbia River smelt have been recently included in the tests.

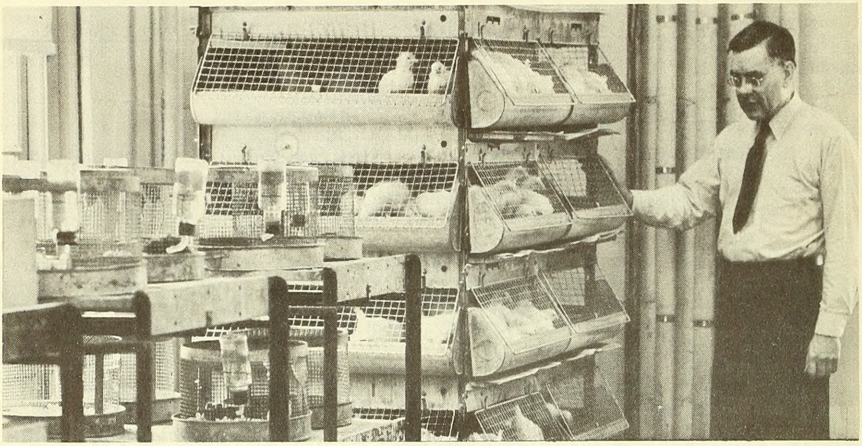
BYPRODUCTS

1. Vitamin content and nutritive value of fishery byproducts.

a. COMPOSITION: Microbiological assays: Series of samples (raw fish, fish from the cooker, press cake, foots from the press, stickwater, and meal) from three byproducts companies were analyzed for vitamin, oil, and moisture content. Vitamin assays were made for riboflavin, niacin, and vitamin B_{12}. High concentrations for all these vitamins were found in the stickwater. There was little or no loss of the vitamins in the preparation of the meal from the press cake. Solvent extraction of raw fish resulted in a definite loss of niacin and some decrease in vitamin B_{12} in the final meal. Analyses of 8 visceral organs of the sardine showed that the kidney had by far the highest vitamin B_{12} content, with the liver ranking second.

Biological assays: A number of assays with chicks have been conducted to determine the vitamin B_{12} content of fish meals and fish solubles. The data indicate that the vitamin B_{12} content of the meals is fairly uniform. The vitamin B_{12} content of the condensed fish solubles seems to vary considerably. All samples which have been assayed have been sent to the Seattle laboratory for microbiological assay. A limited number of assays will be conducted during the coming year.

b. EXPERIMENTS ON UNKNOWN GROWTH FACTORS: Since the discovery of vitamin B_{12} there has been a growing interest in other unidentified growth factors. It has been reported by numerous workers that fish are an excellent source of at least one of these factors.



CHICKS USED TO DETERMINE THE VITAMIN B_{12} CONTENT OF FISH MEALS AND SOLUBLES AT THE SERVICE'S COLLEGE PARK FISHERY TECHNOLOGICAL LABORATORY.

Experiments on growth factors in fish have been carried out with two objectives in mind: (1) Development of fractionation procedures for concentrating any growth factor; (2) Establishment of a microbiological assay for the fish factor which would circumvent the long, laborious chick assay.

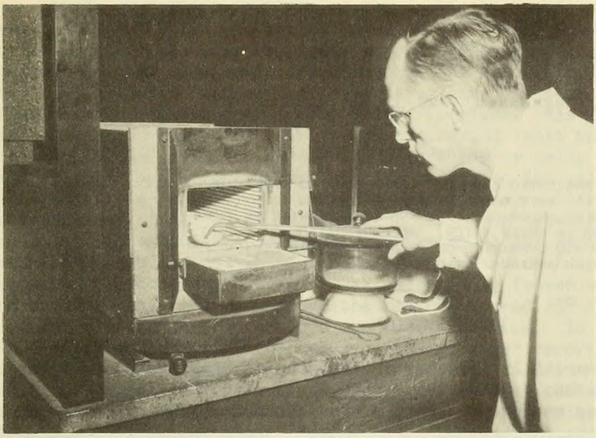
c. NUTRITIVE VALUE OF PROTEIN: A limited number of meals and condensed fish solubles have been fed to chicks to determine the nutritive value of the protein. Quite variable results have been obtained which cannot at the present time be correlated with known differences in raw materials or processing methods used. Further tests are contemplated during the coming year in order to determine reason for variable results.

2. Utilization of viscera from round (whole) fish frozen at sea. No work was done on this project. Work will be initiated as large quantities of materials become available from the freezing-fish-at-sea operations of the Delaware.

3. Study of pharmaceutical and other industrial products from salmon eggs. As an initial step in the characterization of salmon egg protein, analyses of the "essential" amino acid composition by microbiological assay methods are presently being carried out. The work to date on lipid-free protein preparations, from samples of mature pink salmon (*Oncorhynchus gorbuscha*) eggs, reveals that the protein of the eggs from mature salmon of this species is a very good source of all of the ten essential amino acids.

4. The development of a dried product from condensed menhaden solubles or stickwater. During the late summer of the previous year work was begun on this project on the recommendation of members of the menhaden industry. Most of the time has been spent on making dry concentrates of condensed solubles, using fish meal and dry fish scrap as absorbents. Concentrates containing 60 percent of the

dry matter from solubles have been prepared and could be produced commercially with but little change in equipment. Present work deals with producing a dry product without the use of absorbents. Samples of menhaden meal and solubles collected in the field have been analyzed to determine chemical and physical constants and the variations which might be expected. The work on producing dry solubles will be continued during the coming year.



TECHNOLOGIST PREPARING CRUCIBLES FOR ASH DETERMINATIONS OF CONDENSED FISH SOLUBLES AT THE SERVICE'S COLLEGE PARK TECHNOLOGICAL LABORATORY.

SANITATION AND BACTERIOLOGY

1. Industrial waste pollution study. Phase 1, an inventory of the current pollution situation, and phase 2, economic evaluation of the fisheries adversely affected by industrial pollution, have been completed. Phase 3, summation of the first and second phases, with recommendations and suggestions, was completed by June 30 and the project terminated.

FISH PROCESSING HANDBOOK FOR THE PHILIPPINES

Fish is second only to rice as a food in the Philippines. This handbook, intended for both home and commercial processors of Philippine fishes, covers the handling of fresh fish, the various methods of preserving fish--freezing, salting, drying, smoking, canning, and miscellaneous methods such as pickling--and the spoilage of fish and fish products. It gives a step-by-step description of Philippine fish-preserving methods with suggestions on improving them, and of methods used in other parts of the world which have been adapted for Philippine use by the Philippine Fishery Program of the U. S. Fish and Wildlife Service. Tables of useful data for fish processors and of drawings of common species of Philippine fish are included.

By Arthur C. Avery. Research Report No. 26. Fish and Wildlife Service, Washington, D. C. (1950), 149 pages. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 50 cents.

FREEZING FISH AT SEA--NEW ENGLAND

PART V - FREEZING AND THAWING STUDIES AND SUGGESTIONS FOR COMMERCIAL EQUIPMENT

By H. W. Magnusson* and J. C. Hartshorne*

ABSTRACT

DATA ARE PRESENTED ON PILOT-PLANT STUDIES OF FACTORS EFFECTING THE (1) RATE OF FREEZING WHOLE ROUND FISH IN REFRIGERATED SODIUM-CHLORIDE BRINE AND (2) THE RATE OF THAWING FROZEN FISH IN FRESH WATER. RECOMMENDATIONS ARE MADE FOR THE DESIGN AND OPERATION OF COMMERCIAL-SIZE EQUIPMENT FOR FREEZING FISH ABOARD A VESSEL AND FOR THAWING THEM ASHORE.

INTRODUCTION

The feasibility of commercially freezing fish at sea for thawing and processing into fillets ashore depends considerably on the costs of installing and operating the necessary freezing equipment aboard a vessel and the thawing equipment ashore. These costs are directly related to the size and complexity of the equipment, and these, in turn, depend to a large extent on the freezing and thawing characteristics of the fish to be handled. The time required to freeze fish is a prime factor in determining the size of the freezer required to handle the fish as fast as they are caught. Data on thawing rates is also needed to determine the space requirements for thawing equipment.

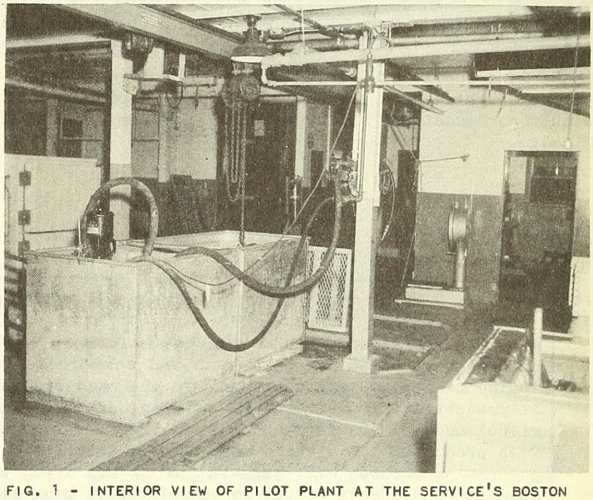


FIG. 1 - INTERIOR VIEW OF PILOT PLANT AT THE SERVICE'S BOSTON FISHERY TECHNOLOGICAL LABORATORY.

Experimental investigations to secure the necessary data on freezing and thawing rates for the commercially-important groundfish of the New England area are being carried out at the Service's Boston Fishery Technological Laboratory (figure 1). The first studies, reported in this paper, were primarily concerned with freezing whole round haddock and cod by immersion in a sodium-chloride brine (in this paper referred to simply as "brine") and thawing them in fresh water. The reasons for limiting the first studies to these freezing and thawing methods were given in detail in an earlier paper in this series (Magnusson, Pottinger, and Hartshorne 1952). After the basic conditions and characteristics of these methods are fairly well understood, it is intended that other freezing and thawing procedures will be studied in detail.

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FREEZING RATES

REVIEW OF EARLIER STUDIES: A few earlier investigators have reported on the rates of freezing fish in refrigerated brine. Plank (1917) developed formulas for calculating the time required to freeze fish of different thicknesses in brine and also in air. He made several assumptions concerning the conductivity of the meat of frozen fish and of the fatty layer near the skin, and concerning the rate of transfer of heat across a fish-brine interface. His few laboratory trials indicated the formulas were fairly satisfactory, at least under certain defined conditions. Tanaka (1949) revised Plank's formulas by using different constants for heat transfer and conductivity. He also modified the calculations slightly by considering the fish to be a conically-shaped body rather than a perfect cylinder. He found that his experimental data, obtained on freezing three fish, compared well with his calculated formulas. Dunkerley (1918) reported on experiments to determine the time required to freeze eviscerated fish in brines of different temperatures. He considered the fish as essentially frozen when a mercury-in-glass thermometer, inserted just above the backbone, read 25° F. He proposed a simple formula relating the temperature and freezing rates. In 1920 (Committee 1920) there appeared a fairly thorough but "preliminary" report on a study of the practicability of freezing fish, especially herring, in brine at a shore plant. Later Stiles (1922) made a scholarly investigation of the problem, using uniform cylinders of a 5-percent gelatin solution and noting the temperatures at several points therein with thermocouples. Taylor (1927) summarized and interpreted some of the above reports. He especially noted the advantages of freezing in refrigerated brine. These reports quite thoroughly considered the theories involved and noted the effects on the freezing rates of several factors: the brine temperature, the brine flow, the thickness and the shape of the fish, the insulating effect of the skin and the fat layers, and so forth. Unfortunately none of these workers took all these factors into account in tests on whole round groundfish. Although many valuable ideas may be gathered from their reports, it is not possible to apply their data directly to the problems of freezing trawl-caught fish aboard a vessel. Therefore, several pilot-scale brine-freezing trials were required to accumulate data on the rates of freezing of round cod and haddock (the most important commercial groundfish in New England waters).

EXPERIMENTAL STUDIES: The pilot-plant scale experiments made to determine the time required to freeze fish in refrigerated brine have been carried out in a specially-built tank, with inside dimensions of 30 by 30 by 30 inches (figure 2). The sides of this tank are encircled with freon-refrigerated coils, and the tank is well insulated. The net refrigerating capacity of the equipment is about 2,000 B.T.U. per hour; on a continuous basis about 50 pounds of fish can be frozen every three hours. For the bulk of the experiments the tank was equipped with a four-section screen-drum mechanism rotated at five revolutions per minute. Although each of the four sections of the drum could hold over 30 pounds of fish, generally less than 15 pounds were placed in each section in order to obtain complete freedom of movement of the fish.

These experiments were all performed with fish at least 24 hours out of the water. For most of the trials, whole round fish were used. It is realized that a commercial freezing-fish-at-sea operation would freeze fish that are only a few minutes, at most a few hours, out of the water. However, it is impossible to secure such fresh fish for use in shore laboratory experiments. Although no marked differences in freezing characteristics are expected, thorough freezing-rate trials with fish right out of the water are contemplated for some trips of the experimental trawler Delaware.

In the experimental pilot-plant scale trials ashore, the freezing rate was followed by periodically removing one or two fish, cutting them vertically at the point of maximum girth, and measuring the depth (from the side) of the frozen layer. On a cross section of a fish, made by cutting or sawing, the line dividing the frozen and unfrozen portion was easily distinguished. With cod and haddock of average size frozen at the lower temperatures, the "depth of freeze" could be easily measured with a precision of 1/16 inch, especially during the first few hours of a freezing operation at 10° F. or lower. Near the centers of very large fish (over 10 pounds) frozen at 0° F. to 10° F. and of smaller fish frozen at higher temperatures, the lines of demarcation between the frozen and unfrozen meat of the fish were not so distinct. A thin metal-stemmed thermometer inserted at the dividing line between the frozen and unfrozen portion regularly read between 25° F. and 28° F. After the first 30 to 45 minutes, the temperature of the unfrozen center of the fish was uniformly at about 30° F. to 32° F. At the same time, the temperature of the frozen portion near the skin approached the temperature of the brine.

In the temperature range (0° F. to 15° F.) of the brine in the experimental trials, the data indicate that the time required to freeze to a given depth is inversely proportional to the difference between the brine temperature and 30° F. Whereas a 10-pound cod in brine at 10° F. takes about 100 minutes to freeze to a depth of one inch (measured from the side), in brine at 0° F. the same depth is frozen in about 60 to 65 minutes. On the basis of this relationship between temperature and time required to freeze, all results from the pilot-plant trials were converted to the time required to freeze to the various depths in brine at 0° F. and at 10° F.; this conversion of the data to comparable bases implemented their correlation and interpretation. The results indicate that cross sections (of about the same area) of cod and haddock freeze at essentially the same rates.

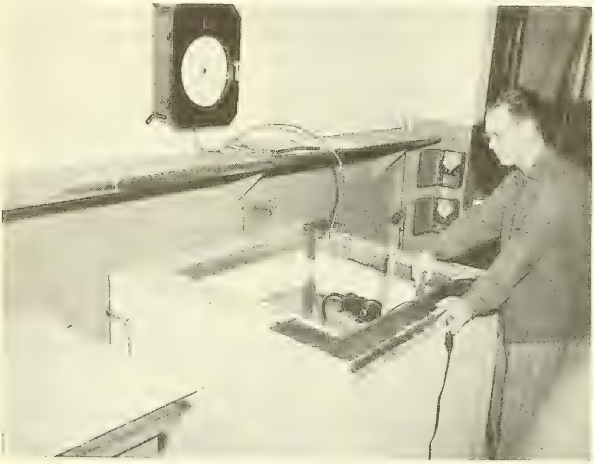

FIG. 2 - EXPERIMENTAL FREEZING TANK.

Figure 3 (a cross section of a ten-pound cod near the thickest part of the fish) illustrates the freezing rate when the fish is moved at a moderate speed (5 to 10 feet per minute) through brine at 10° F. Until the depth of the frozen layer equals three-fourths of the radius of the cross section, the time (T) required to freeze to a given depth (D) is approximately proportional to the product of the depth and the depth plus one-half inch: $T = k\,(D)\,(D + \frac{1}{2})$, where k is a constant dependent on the temperature of the brine. It will be noted that the rate of freezing decreases as the depth already frozen increases. However, the last quarter of the radius was found to freeze in about half of the time predicted by this relationship. Thus, the total time to freeze completely a fish of a given radius is considerably less than the time to freeze to the same depth in a larger fish. The

rates required to freeze completely (temperature throughout below 25° F.) whole round cod and haddock of various sizes moving in brine at 10° F. and at 0° F. are given in table 1 and figure 3. These rates are all conservative estimates, and therefore they are subject to later revision, probably downward, when more extensive experiments have been conducted.

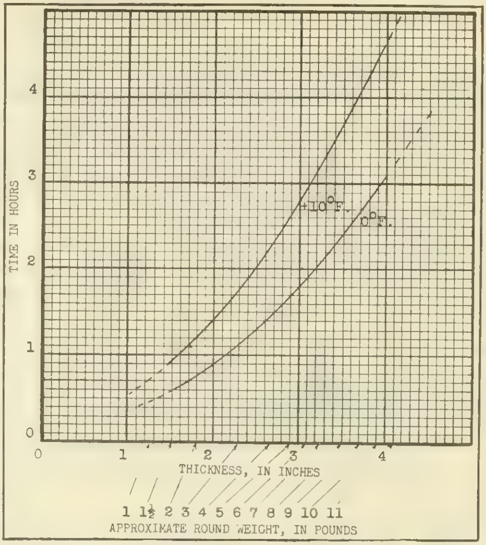

FIG. 3 - THICKNESS OF COD OR HADDOCK VS. TIME REQUIRED TO FREEZE IN BRINE AT 0° F. AND 10° F.

If the effects of friction are disregarded, an infinitely fast movement of brine over the surface of the fish should yield the ideal condition, wherein the surface is continuously held at exactly the temperature of the brine. Stiles (1922) noted that the ideal condition was nearly approximated (at least 85 percent) with even a moderate movement (10 feet per minute) of the brine; presumably this is because of the relatively slow rate of heat transfer through the skin and the meat and the high heat capacity of the brine. In trials conducted in the pilot-plant freezing tank, when a fish was held still in brine at 5° F., and the latter was not circulated, temperatures in the brine approximately 1/8-inch from the fish rose to as high as 15° F. When the brine was circulated even mildly (e.g., 0.1 ft. per minute), the temperatures of the brine near the fish were the same as the temperature of the bulk of the brine. When brine was pumped at rates of over 25 feet per minute past a fish suspended in a cylinder, the freezing rate was not much faster than when the brine was circulated past a fish at about 0.1 foot per minute. Other tests showed that the rate of freezing was essentially the same whether a fish was in the drum rotating at 5 r.p.m. or 1 r.p.m. or was simply held under the surface of the brine with a screen and the screen rapidly raised and lowered about 10 or 15 times during the entire freezing period. Thus, there seems to be little advantage to the movement of brine past the fish surface at high velocities.

The shape of the cross section of a fish was found to have considerable effect on the time required to completely freeze the fish. For fish of equal weight and with approximately equal cross-sectional areas, the most elliptical (that is the least circular) froze in the least time. A flounder (lean like haddock) was completely frozen long before a haddock of equal weight or cross-sectional area. On the other hand, when fish of equal thickness are compared, the roundest freezes fastest. According to a few trials, a cross section of a flounder two inches thick (the vertical axis) with the other (horizontal) axis about ten inches, required about 25 percent more time than a haddock two inches thick.

After the elapse of only half of the total time necessary to freeze the fish completely, the depth frozen is more than three-fifths of the distance from side to the center. At this stage the unfrozen area of the cross section at the point of maximum girth is less than one-sixth of the total and, as the fish has a tapered or cone-like shape, only about one-tenth of the entire fish is not frozen.

When three-fourths of the total time has elapsed, the freezing of the fish is well over 95 percent complete. It should be noted that the last portion of the fish to freeze (see figure 4) is generally part of the viscera. It is not that this part resists freezing, but simply that the point farthest from all surfaces is in the viscera.

The changes in temperature of the brine during the freezing experiments were followed with a recording thermometer sensitive to ± 0.5° F. The temperature normally rose rapidly during the first few minutes, usually reaching a maximum in 15 to 45 minutes. The amount of the temperature rise depended primarily on the weight of fish frozen. For instance, in one trial with 50 pounds of fish, the temperature of the brine rose more than 5° F. The time of the maximum temperature depended to some extent on the weight of fish in the lot, but mainly it depended on the sizes of the individual fish. For example, with a load of scrod the highest temperature was reached in about 15 minutes; with large haddock the temperature peak came after a half hour or more. Calculations based on the temperature records, the heat capacity of the brine, and the weight of fish indicate that scrod (1½ to 3 pounds round weight) are half frozen after 12 to 15 minutes in brine at 10° F. This is about one-sixth or one-seventh of the total time required to freeze completely fish of this size. This result compares well with calculations based on the depth of freeze versus time data.

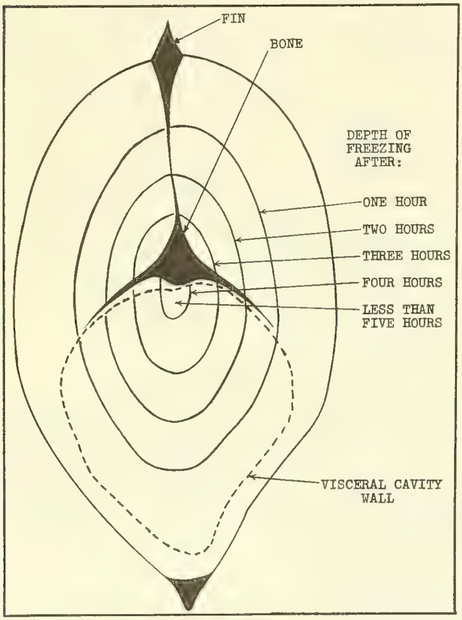

FIG. 4 - PROGRESS OF FREEZING OF 10-POUND COD IN CIRCULATING BRINE AT 10° F.

Trials in which the rotating screen drum was removed from the tank and the fish were held in a basket or a bag, or were allowed to float freely, and the brine was circulated, demonstrated the need for keeping the fish agitated and separated. The buoyancy of the brine (sp. gr. 1.15) on the fish (sp. gr. 1.00) made it difficult to secure adequate agitation of the fish by simply circulating the brine. The fish "packed" together into a mass which, if allowed to remain undisturbed, froze slowly, like a single very large fish. Bags or baskets more than half filled with fish, even though often rapidly raised and lowered and even occasionally turned over, often caused the fish to "pack" together and the freezing of all the fish was not completed in the expected time.

In freezing trials using the rotating screen drum, no "packing" was encountered when the weight of fish in a section was 25 pounds or less. However, in tests with 28 or more pounds in a section there was definite evidence of insufficient movement; on several fish there were soft spots even after they had been in the refrigerated brine at 10° F. for an hour. As the net volume of each section was 1.25 cubic feet, the critical point for this apparatus was approximately 20 pounds per cubic foot of container volume.

FREEZING EQUIPMENT SUGGESTIONS

On the basis of the pilot-plant scale experimental observations and data, several suggestions and proposals can be made concerning possible equipment for freezing fish in brine aboard a fishing vessel.

BRINE TEMPERATURE: Other things being equal, it is obviously advantageous to have the brine as cold as possible. With colder brine, the freezing times would be shorter (see table 1) and, therefore, more batches of fish could be frozen in a day. However, with sodium-chloride solutions there are very definite limitations on how low the operating temperature can be.

Table 1 - Freezing Time for Whole Round Cod and Haddock of Various Thicknesses in Circulating Sodium-Chloride Brine at 10° F. and 0° F.

Thickness 1/	Approximate 2/ Round Weight	Freezing Time 10° F.	Freezing Time 0° F.
Inches	Pounds	Minutes	Minutes
$1\frac{1}{2}$	$1 - 1\frac{1}{2}$	55	35
2	$1\frac{1}{2} - 2\frac{1}{2}$	85	55
$2\frac{1}{2}$	3 - 5	125	80
3	$4\frac{1}{2} - 7\frac{1}{2}$	170	110
$3\frac{1}{2}$	7 - 10	220	145
4	9 - 12	280	185

1/ SIDE TO SIDE THICKNESS (SMALLEST DIAMETER OR VERTICAL AXIS OF A CROSS SECTION) AT THE POINT OF MAXIMUM GIRTH.
2/ ROUND WEIGHT IS GENERALLY 10 TO 15 PERCENT HIGHER THAN DRESSED WEIGHT.

Several practical considerations, such as the troublesome formation of ice on the refrigerant-cooled surfaces, prevent a close approach to the limiting temperature (6° F.) where even eutectic (23.3 percent by weight, 88.3 degrees salometer) sodium-chloride solution freezes solid. Salt will crystallize out at temperatures well above -6° F. from brines stronger than eutectic. For example, salt will separate from a 25-percent (95 degrees salometer) brine at above 14° F. Brines weaker than eutectic, e.g., 21 to 22 percent (80 to 84 degrees salometer) are recommended in order to reduce the possibility of salt depositing at some critical point in the system. On the *Delaware* the planned operating temperature of the brine (21.1 percent, 80 degrees salometer) is between 5° F. and 10° F.

EQUIPMENT DESIGN: To make most effective use of whatever temperature is attained, the freezing equipment must be designed and operated to give efficient transfer of heat from the fish to the brine. According to laboratory and pilot-plant experiments, to accomplish nearly maximum efficiency it is simply necessary to maintain either a moderate movement of the brine over the surface of every fish or of the fish through the brine. Unfortunately, because of the tendency for the fish to float and "pack" at the surface of the brine, this is not easily accomplished when large quantities of fish are handled. The pilot-scale tests indicate that if the fish are to be free to move, the maximum safe load is about 20 pounds per cubic foot of useful space (the net volume of the baskets or sectors enclosing the fish).

The movement of the fish through the brine appears to be far more practical than the circulation of the brine past the fish. For example, to accomplish the same relative movement at the interface, either one part of fish must be moved a foot to the right, or 3 to 5 parts of brine must be moved a foot to the left. Furthermore, unless the brine flow rate is very high and properly directed, the moving brine will not break up the "packs" of fish. To change the direction of brine flow frequently would not be economically feasible.

On the other hand, moving the fish with a rotating, divided screen-drum immersed in a tank of brine proved simple and effective in the pilot-plant trials. At each rotation, the fish (if not too tightly packed in the enclosure) became rearranged and all surfaces were frequently bathed with new refrigerated brine. The

drum must be divided lengthwise, or have baffles to keep the fish moving and turning. In order to allow for keeping the various sizes and species in separate lots, the drum recommended for the Delaware included several sections.

The advantage of using bags to hold the fish rests in a possible reduction in the labor needed to unload the freezer tank and later the vessel (the frozen fish might be left in the bags until the thawing operation was completed). The disadvantages include the extra labor of placing the fish in the bags, the problems connected with removing the fish from the bags, the reduction in the capacity of the freezing equipment (because of "lost" space between bags), and the cost of the bags. The pilot-plant trials (in which bags were used to hold the fish) were successful if the bags were only about half full. Therefore, if bags are used, the capacity of the freezing equipment would be less than if the fish are loose.

A possible alternate for the rotating drum would be a system of rectangular baskets of metal mesh fitting smoothly into a framework in a tank. The baskets would be raised and lowered in the tank to provide the necessary movement and agitation. According to the pilot-scale trial results, the baskets would not have to be moved often; once per minute would be more than sufficient if full advantage is taken of the circulation of the brine to and from the heat exchanger. The experiments indicated that the speed with which the baskets are raised is most important. The power required to raise the baskets may be excessive unless very light baskets can be employed. Possibly the cover alone could be moved to provide the necessary agitation during the freezing period. The baskets could fit closely into a tank and thus the non-working volume of brine within the freezer could be held to a minimum. In the basket-type freezing system, it might be practical to have several more or less independent small tanks. This would be advantageous because it would be possible to circulate brine in only those tanks in use. It would be practical to drain one tank at a time for cleaning or (if desirable) during an unloading operation. Furthermore, a leak or other minor trouble would often affect only one tank and the others would still be available for freezing.

EQUIPMENT SIZE: The proper size of the freezing equipment depends on the time required to freeze, the rate at which fish are caught, the distribution of species and sizes of fish, and the average fraction of the total catch to be frozen immediately after being caught. Only the first factor will be discussed in detail. For the Delaware it was planned that for experimental purposes a part of the catch would be iced in the normal manner and, therefore, the estimated desired freezing capacity was set at only 1,000 pounds of haddock or market cod (average round weight, six pounds) per hour. The chosen refrigeration machinery (an absorption-system plant) has a rated capacity of 25 tons per 24-hour day. This capacity is in excess of the present freezing and storing requirements and would therefore permit future enlargement of the freezing equipment. It is also sufficiently oversized to handle larger than average freezing loads (possibly up to 1,500 pounds per hour), such as when smaller fish predominate.

According to the pilot-plant freezer trials, haddock and market cod freeze completely at 10° F. in an average of about three hours. For a rate of 1,000 pounds per hour, the system must, therefore, have a total capacity of 3,000 pounds. At 20 pounds per cubic foot, the net volume of the containers must be 150 cubic feet. The drum mechanism on the Delaware is divided into twelve sections, each of about 12.5 cubic feet. The tank containing this drum is 5 by 5 by 10 feet, or 250 cubic feet.

If a basket system were to be used, a possible arrangement with about the same total capacity might include three separate tanks, each $4\frac{1}{2}$ by 4 feet, and 4

feet deep. Each tank could have two baskets 2 by $3\frac{1}{2}$ feet, and 3-3/4 feet deep, each basket with a net volume of about 25 cubic feet and capable of holding 500 pounds.

If small scrod, weighing $1\frac{1}{2}$ pounds, are being frozen, the time required to freeze would be only about an hour and, therefore, the net capacity of the Delaware's freezing tank could be nearly 3,000 pounds of small scrod per hour, provided the heat exchanger and refrigeration machinery are adequate. When large cod (over ten pounds) are handled, and they are to be frozen completely before removal from the tank, an operation requiring about six hours, the freezing capacity of the equipment would drop to 500 pounds per hour. However, advantage could possibly be taken of the fact that even a fish four inches thick is well over 90 percent frozen after 3 hours in brine at 10° F. The freezing of these large fish could be completed during the first hours of storage mainly by the reserve refrigeration represented by the low temperatures (10° F. to 25° F.) of the already-frozen fish. Even when a variety of sizes of fish are handled simultaneously, it may prove to be most practical to leave all the fish in the brine for the same length of time. The time would be chosen so as to insure at least 90-percent freezing of the largest fish. The extra hour or two in the brine should not seriously increase the salt content or otherwise change the characteristics of the smaller fish.

THAWING RATES

LITERATURE REVIEW: Reports of studies on the thawing of frozen whole fish are far fewer than reports on freezing of whole fish. Stiles (1922) presented some information on thawing rates and problems. He noted that thawing is a relatively slower process than freezing. His data illustrate the decided advantage of thawing in water over thawing in air. More recently, Reay, Banks, and Cutting (1950) reported on a few tests on thawing whole and packaged fish in still and moving water, and air at different temperatures. They concluded that the most practical method for thawing whole fish was in well-circulated, moderately warm water. These reports are based on laboratory or small-scale experiments, generally using fish frozen in air or on plates. Additional information was necessary and, therefore, semi-commercial and pilot-plant trials thawing brine-frozen cod and haddock in water were conducted.

FIG. 5 - EXPERIMENTAL THAWING TANK.

EXPERIMENTAL STUDIES: The experimental equipment and methods used in the pilot-plant tests on thawing in water were very similar to those used in the brine-

freezing studies. The bulk of the data was obtained using the same 30 by 30 by 30-inch tank with the rotating screen drum. Several semi-commercial trials were made in a tank, 8 by 3 by 3 feet (figures 5 and 6) equipped with a 1/3-hp. centrifugal pump to circulate the water. This tank was supplied with cold-water (42° F. to 65° F.) and hot-water (150° F.) inlets and with adequate overflow arrangements. Whole round haddock and cod frozen in the course of the pilot-plant freezing studies were used in most of the thawing trials. For a few of the large-scale thawing experiments, fish which had been frozen in brine aboard the Delaware were employed.

The progress of thawing was followed by occasionally cutting one or more fish with a sharp, sturdy knife and measuring the thickness of the thawed layer. The line between the thawed meat of the fish and the still frozen meat was quite clear and definite. During at least the first four hours of thawing, unless the fish were old and soft (from repeated freezing and thawing), the thickness of the thawed layer could be estimated to within 1/16 of an inch. The temperatures at various depths were determined by inserting a thin-stemmed metal thermometer at several points in cross-sectional cuts. After 30 minutes of thawing, the temperature of the center of a cod or haddock, weighing from 1 to 15 pounds, had risen to between 25° F. and 30° F. The borderline between the frozen and thawed layers was between 30° F. and 32° F. The temperature of a given point in the thawed layer depended on the location of the point and on the temperature of the thawing water. Figure 6 illustrates the rate of thawing of a 10-pound cod, near the thickest part of the fish, when it was moved through 60° F. fresh water at about 10 feet per minute. By comparing figures 3 and 6 it will be seen that thawing in water proceeds in much the same manner as does freezing in brine. However, presumably because water (thawed meat of fish) has a much lower heat conductivity than ice (frozen meat of fish), thawing at 60° F. is only about half as rapid as is freezing at 0° F. The dependence of the thawing rate on the depth of thawing and the thickness of the fish are the same as described for the freezing process. Also, in thawing, as in freezing, the rate was found to vary directly with the difference between the temperature of the thawing water and 28° F. to 30° F. Conservative estimates of the time required to thaw completely fish of various thicknesses of circulating water at 60° F. are given in table 2.

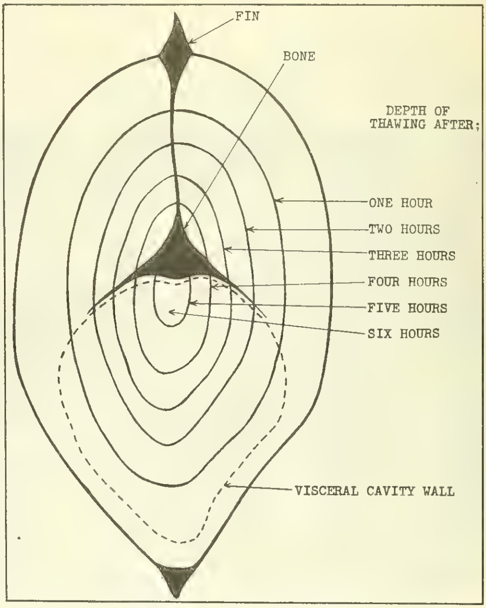

FIG. 6 - PROGRESS OF THAWING OF 10-POUND COD IN CIRCULATING WATER AT 60° F.

The effect of the shape of the cross section of the fish on the rate of thawing and the time required to completely thaw the fish was found to resemble closely the effect on freezing as described in the section in freezing rates. A flounder, which has an elliptical cross

section, thawed in much less time than a round haddock of the same weight. However, the flounder took longer (about 25 percent) to thaw than a haddock of the same thickness. In whole round fish, the last portion to thaw was in the viscera. A large number of partially-thawed fish were filleted in the pilot plant to determine the effect of the degree of thawing on the ease and efficiency of filleting. In these trials it appeared to semi-experienced filleters that almost all, but not necessarily all, the fillet portion should be thawed. When the viscera, the bone, and a thin layer of meat next to the bone were frozen, the fish were easier to fillet than when the fish were completely thawed. Although it might take four hours to thaw a market cod completely in water at 60° F., the fish would be ready for filleting after three hours or less. The last column in table 2 gives a conservative estimate of the time required in water at 60° F. to thaw fish of several size groups sufficiently for filleting. The same data are also presented in figure 7. When larger quantities of fish actually frozen at sea under proper conditions are available, it will be possible to secure better data on the time required to thaw. It is anticipated that the time, especially to thaw sufficiently to permit filleting, will be revised downward from those given in table 2 and figure 7.

Table 2 - Thawing Time for Frozen (0° F.) Whole Round Cod and Haddock of Various Thicknesses in Circulating Water at 60° F.

Thickness 1/	Approximate 2/ Round Weight	Thawing Time at 60° F. Completely	For Filleting
Inches	Pounds	Minutes	Minutes
1½	1 -1½	60	50
2	1½-2½	100	85
2½	3 - 5	150	125
3	4½-7½	210	170
3½	7 -10	280	220
4	9 -12	360	285

1/ SIDE TO SIDE THICKNESS (SMALLEST DIAMETER OR VERTICAL AXIS OF A CROSS SECTION) AT THE POINT OF MAXIMUM GIRTH.
2/ ROUND WEIGHT GENERALLY 10 TO 15 PERCENT HIGHER THAN DRESSED WEIGHT.

Several experiments were carried out to determine the effect of varying the speed of the water moving past the fish on the rates of thawing. When the water was more or less undisturbed, the temperature in the water immediately next to the fish dropped to 12° F. to 15° F. below the temperature of the bulk of the water. Scrod haddock required 1½ to 2 times as long to thaw in "still" water as in moderately moving (10 feet per minute) water at the same temperature. When water (at 65° F.) was pumped past a fish at the rate of 60 feet per minute, or faster, after 15 minutes the depth of thawed meat was about 1/16 of an inch more than when water passed the fish at 1 to 5 feet per minute. After 30 minutes, the difference in the depths of thaw were <u>less</u> than 1/16 of an inch. Thus, circulation of water past a single fish at a moderate, practical rate resulted in thawing rates not more than 10 percent longer than the most rapid circulation possible in the pilot-plant equipment.

The pilot-plant studies demonstrated that it is far easier to agitate fish in fresh water than in brine. It was found that such positive agitation as supplied by a rotating drum was not necessary. Whereas brine has a considerable buoyant effect on the fish, a brine-frozen fish has only a slight tendency to float in fresh water. After only 15 or 20 minutes of thawing in fresh water at 60° F., all or nearly all the fish tend to sink slightly. Tendencies for the fish to float or sink were not sufficient to cause undue "packing." Large lots of loose fish were easily kept moving and separated by a well directed flow of water. After several trials, a quite satisfactory arrangement was developed for circulating water in the 8 by 3 by 3-foot tank. Water was moved by a 1/3-hp. centrifugal pump into a manifold consisting of a two-inch pipe, 7½ feet long, with six 3/16-inch holes equidistant along the length. About 30 gallons of water per minute (under a pressure of about 10 lbs. per sq. inch) were directed through these orifices in the manifold

and across the bottom of the tank. This resulted in a circular movement of all the water in the tank, sufficient to keep the fish from "packing" at the bottom or the top.

In several thawing trials using the rotating drum, the maximum safe load per 1.25-cubic-foot section was found to be between 25 and 30 pounds. Thus, in this well-agitated drum mechanism it was possible to thaw 20 to 24 pounds of fish per cubic foot of enclosure. In trials with the large tank, where agitation was accomplished by means of circulating the water, the safe load was a little smaller. When the space available for use (below the water line and not including the area screened off for the pump) was about 50 cubic feet, the largest load that thawed satisfactorily was 1,000 pounds.

Whereas the lowest temperature that may be safely used in the brine-freezing process is limited by the characteristics of the brine, the temperature of the thawing process is limited by the characteristics of the fish. On the basis of reports on the effect of various temperatures on fish proteins, it was anticipated that temperatures above 65° F. might adversely affect the quality of the fish. In a preliminary experiment to consider the effects of water-thawing at elevated temperatures, several fish were thawed in water at 90° F. A semi-experienced testing group noted nothing unusual about the taste, odor, or appearance of the fillets prepared from these fish. In one trial, when the water temperature rose (accidentally) to about 110° to 115° F., the meat of the fish was partly cooked and fell apart readily. In a well-controlled pair of trials at 53° F. and 72° F., preliminary observations indicate there was no apparent difference before or after cooking between the two sets of fillets cut. It is to be emphasized that in all of the thawing trials the fish were filleted less than two hours after they were completely thawed. Undesirable enzymatic and bacterial actions are to be expected if the fish are held too long at high temperatures.

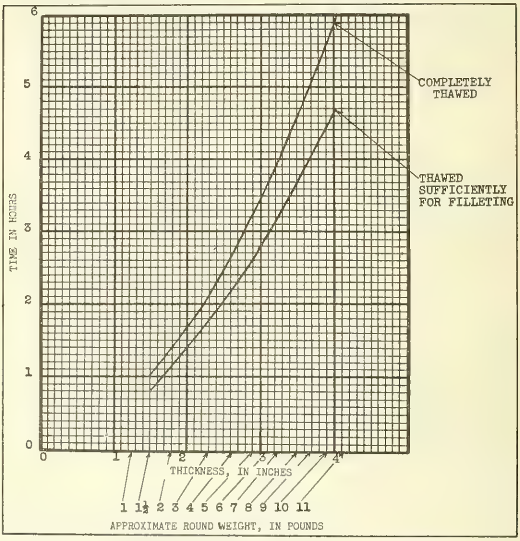

FIG. 7 - THICKNESS OF COD OR HADDOCK VS. TIME REQUIRED TO THAW COMPLETELY AND TO THAW FOR FILLETING IN WATER AT 60° F.

It was interesting to note that when fish frozen at sea were thawed, they appeared to be still in rigor mortis. Even when the fish were completely thawed as checked by knife and thermometer, they were as stiff as half-thawed fish are normally. The stiffness was not a "salt rigor" caused by the immersion in brine, for the rigor passed off after one or two hours. However, even after this rigor was gone, the fish which had been frozen at sea were firmer than the freshest dressed fish normally available ashore.

In the experimental studies, when one fish or only a few fish were being thawed, the drop in the temperature of the water was not sufficient to require

adjustment. When capacity loads were thawed, some provision for keeping the water temperature up was necessary. Otherwise, the thawing process was slowed down. Except in the winter, it was possible to maintain a reasonable (higher than 55° F.) thawing temperature by simply adding a large volume of new "cold" water. (At the laboratory the "cold" water supply varied from 68° F. to 42° F.). In the semi-commercial-scale trials, even in the summer, it was found to be most practical to add a moderate quantity of hot water. The rate of addition of hot water was adjusted as nearly as possible to the demand, which was quite high during the first minute or two and gradually decreased to nothing when the fish were completely thawed.

In a commercial operation it might at times be advantageous to leave a batch of fish in the thawing tank for several hours, for instance overnight. Therefore, some tests were made to find the limitations of such a practice and, if possible, to develop a satisfactory procedure. When fish were loaded into a dry tank and left overnight, in the morning the fish touching the sides of the tank and those at the top of the load were partially or completely thawed, while some fish near the center were still completely frozen. The viscera of the former fish had deteriorated badly. When a load of fish was left overnight in a tank full of water, with no circulation of the water, the fish on the top were thawed and spoiling by morning. The fish in the center of the mass were frozen together. When a load of fish was left overnight in a tank of water with the circulating pump operating, but with no new water being added, the temperature dropped rapidly from 55° F. to about 40° F. in half an hour. The temperature probably dropped further, but by morning it was at 40° F. At that time the fish were all thawed and appeared to be in good condition. This procedure, with some modifications, possibly would be suitable when overnight thawing is desirable. It would be economical and would provide thawed fish in a satisfactory condition to produce good fillets.

A brief study was made of the possibilities of increasing the movement of the fish by injecting air into the thawing water. In a few trials, air and water were pumped into the same manifold. The mixture of air and water appeared to move the fish around more than did water alone. In a few trials, a separate small manifold for air was used. When the fish were kept off the bottom of the tank by a screen "false bottom," the rising air bubbles seemed to prevent any bunching of the fish on this screen.

THAWING EQUIPMENT SUGGESTIONS

TYPE OF EQUIPMENT: On the basis of the pilot-plant trials, a system which moves the fish through the water, such as a rotating drum, seems to be more complicated than is necessary. The most practical system for thawing frozen fish appears to involve a tank of fresh water in which the thawing fish are kept from packing together by the forced circulation of the water. The experiments indicate that the thawing fish can be handled and held satisfactorily in expanded metal baskets which fit the tank with a minimum of waste space. As the deepest tank employed in the thawing experiments was only three feet deep, the characteristics of deeper tanks cannot be safely predicted.

A batch-process thawing system would seem to be the most practical and economical for the average processing plant. A single continuous system would present difficulties every time a shift was made from one size of fish to another. If several sizes of fish were thawed simultaneously, a continuous system would necessarily be geared to the largest, slowest-thawing fish, and meanwhile the smallest, fastest-thawing fish would remain in the water a considerable time after they were completely thawed. A system made up of several small continuous thawers would eliminate some of these problems, but the cost of such a system might be excessive and in some plants it would be very difficult to arrange several thawers efficiently.

The recommended system would consist of one or more tanks equipped to circulate water at a maintained desired temperature. The fish would be handled in expanded metal or wire-mesh baskets, each holding between 200 and 500 pounds. The baskets would be transported from the delivery or loading area to the tanks and thence to the scaling equipment or tables by means of an overhead monorail and hoist. The sizes and shapes of the tanks and baskets would be adjusted to make full use of the gross volume of the tank, leaving about three inches at the bottom for a circulating-water manifold and for the unimpeded flow of the water across the bottom of the tank. In a full commercial-scale operation, it may develop that a perforated false bottom one or two inches off the tank bottom might be desirable to provide a space for sand, scales, and other debris to collect. The tank would be equipped with an overflow outlet arranged to skim the surface and remove foam and floating debris. The water could be circulated with a standard centrifugal pump attached to two holes in the side or end of the tank. The pump outlet would connect to a manifold lying along the bottom of the tank. The orifices in the manifold would direct the water across the tank; the number and size of the orifices would necessarily be adjusted to the particular pump's characteristics to secure most effective circulation.

FIG. 8 - EXPERIMENTAL THAWING TANK, SHOWING CONSTRUCTION OF BASKETS FOR HOLDING FISH. HINGED DOOR FACILITATES REMOVAL OF THAWED FISH.

THAWING-WATER TEMPERATURE: Although a few experiments indicated that considerably higher temperatures probably could be used with safety, yet at this time no recommendation will be made for using thawing water warmer than 65° F. In fact, as an extra margin of safety, all the suggestions in this section are based on a normal operating temperature of 60° F. When there is a definite need for slowing the thawing process, as when the fish are left in the thawing tank overnight, water considerably cooler than 60° F. should be used.

The desired temperature in the thawing water can be maintained in several ways. The most practical in any given situation would depend on the facilities available and the local unit costs for utilities and fuel. It is easiest to evaluate the methods on the basis of the heat requirements for thawing a definite load of fish, for example, 1,000 pounds. If this weight of fish is at 0° F. when it enters the tank and at 60° F. when it leaves, the heat absorbed by the fish would be close to 150,000 B.T.U. (British thermal units). That amount of heat must be supplied the system for each 1,000 pounds thawed. If the frozen fish were as warm as 20° F. when placed in the tank and the final product was only 90-percent thawed, the heat requirements would be about 110,000 to 120,000 B.T.U.

The simplest system for replacing the heat lost to the fish would be to add new water continuously. If water at 65° F. (occasionally available from Boston water mains) were added, and the operating (and thus overflow) temperature was 60° F.,

at least 30,000 pounds of water would be required for thawing 1,000 pounds of fish. This quantity of water, at $1.30 per 1,000 cubic feet, would cost 65 cents. A system similar to the one used in the pilot-plant studies, where hot water is added, usually would be less expensive, and it could operate at any desired temperature at any time of the year. To furnish 150,000 B.T.U. to a thawing tank operating at 60° F., about 1,650 pounds (including 10 percent for various losses to sources other than for thawing the fish, e.g., to air surrounding the tank) of water at 160° F. must be supplied. To heat this quantity of water (200 gallons) with manufactured gas at 11 cents per 100 cubic feet would cost about 43 cents. If coal or oil were used as fuel, this cost would be about 19 cents. In either case, the cost of the water needed, including the prorated part of the original load, would be about 5 cents. It should be noted that a moderate overflow (wastage) of water is desirable, for it would carry off floating debris, fish slime, and foam.

Heating the water directly could be done with an immersed heat exchange flue and an atmospheric gas burner, or with steam coils either in an auxiliary tank or in the main tank itself. The simplest equipment for heating would probably be electric unit heaters. At three cents a kilowatt hour, the power costs for thawing 1,000 pounds of fish would be about $1.35. In any system involving reheating the water, it would be necessary to make arrangements to clean the pipes or coils quickly and easily, for the protein from the slime and scales would precipitate and harden on the heated surfaces, thereby both reducing the efficiency of heat transfer and introducing a serious sanitation problem.

SIZE OF EQUIPMENT: The experimental studies indicated that the thawing tank baskets should not be loaded with much more than 20 pounds of frozen fish per cubic foot of free space. In the suggested type of thawing tank, about three-fourths of the gross volume of a well-designed tank would be usable (available for holding fish); thus the tank can hold 15 pounds per cubic foot of this gross volume. To handle a batch load of 1,000 pounds, a tank of 65 to 70 cubic foot is required.

The laboratory trials indicate that it is advantageous to have the water circulating at considerable pressure, ten pounds per square inch or more. For a 70-cubic-foot tank the water should be pumped at 30 gallons per minute or more. For this size tank, a 1/3-hp. and possibly even a 1/4-hp. centrifugal pump would be adequate.

The daily capacity of any thawing equipment will, of course, depend on the sizes of the fish being handled, the temperature of the water, and the number of hours per day the equipment is operated. If the water is held at 60° F., the tank would be in use for 90 minutes to thaw a batch of scrod haddock or scrod cod. A batch with fish weighing 6 to 7 pounds each, would keep the tank occupied about 3 hours. The largest haddock and market cod would require 4 or 4½ hours, while large and extra-large cod would keep the tank in use even longer. If the sizes of cod and haddock to be processed are distributed over the full range, a possible scheme for fully utilizing the equipment would be as follows: overnight (4 p.m. to 7 a.m.) thaw the largest cod at a temperature, for instance, of 45° F., chosen to assure complete thawing of all the fish by morning. Next, thaw the scrod (7:00 to 8:30 a.m.), which would be ready before the filleters have finished with the easily-handled large cod. While the time-consuming scrod are being filleted, thaw the larger haddock and market cod (8:30 a.m. to 12:30 p.m.), and finally thaw the small haddock and market cod (12:30 to 3:30 p.m.). If only scrod were handled, and the thawing was started before the filleting operations, five or six batches could be thawed in a day. Thus a 1,000-pound-batch tank would supply the filleting line with 4,000 to 6,000 pounds of whole round fish, the equivalent of 3,500 to 5,000 pounds of the dressed fish now normally handled.

SUGGESTED COMMERCIAL INSTALLATIONS: The proper design for a thawing installation at any specific processing plant would depend on several factors, especially on the size and shape of the usable floor space and on the availability of the necessary utilities. Two suggested designs for thawing tanks are detailed here. The one tank is comparatively small so that it can be moved, if necessary. It could thaw batches of 1,000 pounds of fish and compares closely with the tank in use in the pilot-plant studies. Several of these small units could be built and operated almost as economically as could a single large tank. The large tank suggested is intended for thawing approximately 30,000 pounds of fish per working day in four batches of 7,500 pounds each.

The recommended movable tank would be 8 feet long, 4 feet wide, and 2½ feet deep. It would be built of 16-gauge sheet iron reinforced with split pipe or angle irons, and galvanized. Openings would be provided in the end wall and the bottom for the drains and the water-circulating system. It might be desirable to have a perforated false bottom about one or two inches off the bottom. The circulating system could consist of a manifold with drilled holes, fed water under pressure by a centrifugal pump with a 1/4- or 1/3-hp. motor. At a "T" connection on the inlet side of the pump, hot water at 150° to 180° F. would be added. The rate of addition of hot water could be manually controlled, but an automatic control valve actuated by the tank water temperature would be better. Baskets for handling the fish would each be approximately 44 by 21 inches and 27 inches deep, so that four would fit easily into the tank. Above the tank (or tanks) and extending to the loading area and to the scaling equipment would be a monorail and hoist for moving the fish from one step of the operation to another.

A single large tank to handle 7,500 pounds of frozen whole round fish per batch might have the following dimensions: 4½ feet wide, 3½ feet deep, and 35 feet long. The water could overflow into a separate tank for heating. This tank, possibly 4½ by 3½ by 5 feet, would be fitted with steam-heated coils with a feed valve automatically controlled by the thawing-water temperature. From this separate tank the water could be circulated back to the thawing tank under considerable pressure by means of a centrifugal pump and a manifold. A simple framework would support the baskets at about four inches off the bottom. Each of 15 baskets would be of expanded metal on an angle iron frame, 4 feet by 2 feet and 3 feet deep, inside dimensions. A monorail system would move the fish from the loading areas to the tanks and from there to the scalers.1/

THAWING COST ESTIMATES: It is difficult to present any cost figures that would be generally applicable. Therefore, the following figures are simply estimates. However, it is believed they tend to be conservatively high.

A small operation designed to handle about 8,000 pounds of round fish per day would require two of the movable tanks described, a monorail and hoist, and a 130,000-B.T.U. hot-water heating system. These would cost roughly $1,500. The larger tank described, together with a monorail system, but not including the steam source, might cost in the vicinity of $2,800.

The estimated operating costs attributable to the thawing of brine-frozen fish (if coal or oil is used as fuel) for each 1,000 pounds of round fish would be approximately: water, 5 cents; fuel, 19 cents; electric power, 2 cents; labor, 15 cents--a total of 41 cents per 1,000 pounds.

1/ IT HAS BEEN IMPOSSIBLE TO CONSIDER ALL THE POSSIBLE VARIATIONS IN CONDITIONS AND REQUIREMENTS OF PROCESSING PLANTS. NOT ALL THE IDEAS NOR MANY OF THE DETAILS DEVELOPED IN THE PILOT PLANT COULD BE INCLUDED IN THIS PAPER. IT IS RECOMMENDED THAT EACH FIRM CONTEMPLATING THE INSTALLATION OF A THAWING TANK CORRESPOND DIRECTLY WITH THE BOSTON FISHERY TECHNOLOGICAL LABORATORY.

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CURING OF FISHERY PRODUCTS

Fish curing is an important method of preservation in the fishing industry and in the trade generally, but information on the principles involved in the salting and smoking of fish commercially is widely scattered. This report is a reference handbook on the problems of fish curing. It includes information from recent technical studies of the principles on which fish curing is based, discusses improvements in methods and equipment, and describes the standard methods.

By Norman D. Jarvis, Research Report No. 18. Fish and Wildlife Service, Washington 25, D. C. (1950), 270 pages. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 75 cents.

FREEZING AND COLD STORAGE OF PACIFIC NORTHWEST FISH AND SHELLFISH

PART I - STORAGE LIFE OF VARIOUS ROCKFISH FILLETS

By D. T. Miyauchi* and M. E. Stansby**

ABSTRACT

DATA ON INITIAL PALATABILITY AND COLD-STORAGE (0° F.) KEEPING QUALITY ARE PRESENTED FOR SINGLE SAMPLE LOTS OF SEVEN SPECIES OF PACIFIC COAST ROCKFISH, PACIFIC OCEAN PERCH, AND FOR OCEAN PERCH (ATLANTIC) AS A COMPARISON.

INTRODUCTION

Rockfish of the genera Sebastodes and Sebastolobus are landed in large quantities by fishermen along the Pacific coast. These fish are usually filleted and are marketed both fresh and frozen under the general label "rockfish fillets." The various species of rockfish fillets differ in palatability, texture, and cold-storage keeping quality. Cold-storage life of the rockfish fillets is limited largely because of the development of rancidity and undesirable changes in texture.

Table 1 - Description of Nine Species of Rockfish and Cold-Storage Life of the Rockfish Fillets at 0°.F.

Species of Rockfish		General Description	Source of Sample	No. of Fillets per 1-lb. Package	Initial Rating	Quality of Fillets2/ Rating After Storage at 0° F. For: WEEKS					
Common Name	Scientific Name					9-12	13-16	17-20	21-24	25-28	29-32
Pacific ocean perch	Sebastodes alutus	Color: bright carmine-red on dorsal surface; lighter on ventral surface with some silvery sheen. Length: to 19 inches.	Newport, Oregon	4 to 5	VG	G	M	M	M to F	F	U
Lobe-jawed rockfish	Sebastodes diploproa	Color: rose-red to brick-red on dorsal surface; silvery sheen on ventral surface. Length: to 12 inches.	Newport, Oregon	4 to 5	G	M	M	M to F	-	U	
Bocaccio	Sebastodes paucispinis	Color: light-green to dark-brown on dorsal surface; shading into reddish-bronze to white on ventral surface. Length: to 3 ft.	Eureka, California	3 to 5	VG	G	M	M	F	F	U
Chilipepper	Sebastodes goodei	Color: pinkish red on dorsal surface; shading into pink on ventral surface. Length: to 22 inches.	Eureka, California	4 to 5	VG	M	F	F	U		
Orange or red rockfish	Sebastodes pinniger/	Color: light-olive gray with orange-red, red predominating, on dorsal surface; paler to nearly white on ventral surface. Length: to 2½ feet.	Seattle, Washington	2 to 3	VG	M to F	F	F to U	U		
Red rockfish or "red snapper"	Sebastodes ruberrimus	Color: deep vermilion-red on dorsal surface; paler on ventral surface. Length: to 3 ft.	Seattle, Washington 1/	1 to 2	G	M	F	F	F	U	
Vermilion rockfish	Sebastodes miniatus	Color: vermilion-red on dorsal surface; light-red on ventral surface; black dots on back and sides. Length: to 3 feet.	Seattle, Washington1/	1 to 2	G	U3/					
Channel rockfish or "Idiot"	Sebastolobus alascanus	Color: bright-red; dark blotches on fins; cheeks spiny. Length: to 2 feet.	Newport, Oregon	11 to 12	-	-	M	M to F	-	U	
Ocean perch (Atlantic) or rosefish	Sebastes marinus	Color: orange-red or red on dorsal surface; paler on ventral surface. Length: to 2 ft.	Gloucester, Mass.	4 to 5	VG	G	M	M	-	F	U

1/ SAMPLES OF RED ROCKFISH (SEBASTODES RUBERRIMUS) AND VERMILION ROCKFISH (SEBASTODES MINIATUS) WERE PREPARED AT THE FISHERY TECHNOLOGICAL LABORATORY, SEATTLE, WASHINGTON, FROM FISH CAUGHT OFF THE COAST OF WASHINGTON BY THE SERVICE'S EXPLORATORY VESSEL JOHN N. COBB. THESE FISH WERE FROZEN WHOLE ABOARD THE VESSEL. AT THE LABORATORY THE FISH WERE THAWED IN COLD RUNNING WATER AND FILLETED; THE FILLETS WERE PACKAGED AND REFROZEN.
2/ FACTORS DETERMINING QUALITY ARE APPEARANCE, FLAVOR, TEXTURE, AND ODOR; VG = VERY GOOD (HIGHEST PREFERENCE), G = GOOD (NORMAL QUALITY OF FRESH FILLETS), M = MEDIUM (SOME LOSS IN ORIGINAL QUALITY), F = FAIR (APPRECIABLE DETERIORATION IN QUALITY), U = UNACCEPTABLE (POOR TO INEDIBLE).
3/ UNACCEPTABLE AFTER 9 WEEKS.
"-" INDICATES NO OBSERVATION.

The rate of deterioration during storage varies from species to species. This report presents data on the initial palatability and the cold-storage keeping quality of eight species of Pacific coast rockfish (table 1). Data on the ocean perch (Atlantic), Sebastes marinus, a species of rockfish found on the Atlantic coast, are included for comparison. Although this study was limited to storage tests with only one lot of samples for each species, the information may serve as a guide to the commercial processor in the packing and marketing of these fish. It may be advantageous, for example, for the processor to promote separately those species of rockfish which show high acceptability and good cold-storage keeping quality.

EXPERIMENTAL PROCEDURE

Fillet samples of Pacific ocean perch (S. alutus), bocaccio (S. paucispinis), lobe-jawed rockfish (S. diploproa), orange or red rockfish (S. pinniger), chili-

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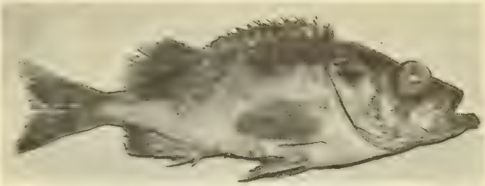
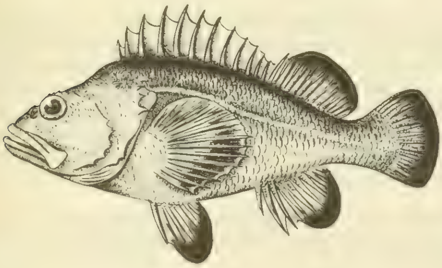
pepper (S. goodei), and channel rockfish or "idiot" (Sebastolobus alascanus) were prepared and frozen in one-pound packages in commercial filleting plants, using regular commercial procedures.



PACIFIC OCEAN PERCH (SEBASTODES ALUTUS)

Samples of vermilion rockfish (Sebastodes miniatus) and red rockfish or "red snapper" (S. ruberrimus) were prepared at the Seattle Technological Laboratory from fish caught off the coast of Washington by the Service's exploratory fishing vessel, John N. Cobb. These fish had been frozen whole aboard the vessel. At the laboratory they were thawed in cold running water and filleted. The fillets were packaged and refrozen. The exact effect of this procedure on the cold-storage keeping quality of the fillets is not known. The results of the storage tests on these samples may be of interest, however, and are included in this report.

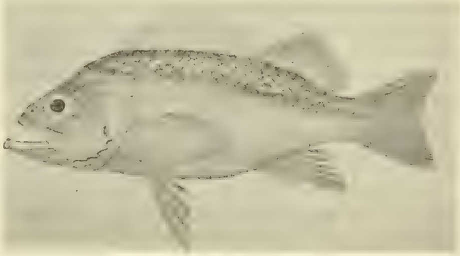
The skin was removed from the fillets of red rockfish (Sebastodes ruberrimus), vermilion rockfish (S. miniatus), and orange rockfish (S. pinniger) before packing and freezing. The fillets of the remaining species were packed with the skin on.



RED ROCKFISH (SEBASTODES RUBERRIMUS)

Samples of ocean perch (Atlantic), Sebastes marinus, fillets were obtained from Gloucester, Massachusetts, where they had been prepared, packaged, and frozen under regular commercial conditions. These fillet samples were shipped frozen (using dry ice) via air express to Seattle, Washington.

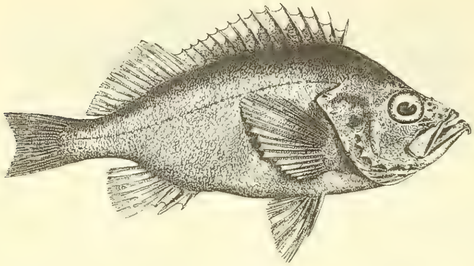
The ocean perch (Atlantic), S. marinus, catch leads that of any other fish in the New England area. Also, the general external appearance of this species resembles that of some of the Pacific Coast rockfish, especially the Pacific ocean perch (Sebastodes alutus). For these reasons it was included in these tests as a basis for comparison.



VERMILION ROCKFISH (SEBASTODES MINIATUS)

All samples were stored at 0° F. Organoleptic observations were made on the thawed fillets and on the cooked product. These tests were made prior to freezing and storage, and thereafter at periodic intervals of several weeks. Two or more packages of fillets of each species were taken from cold storage and allowed to thaw at room temperature. Thawing was hastened by directing the air blown from an electric fan over the packages. Appearance and odor of the thawed fillets were noted.

For tests on the cooked product, 3 to 5 individual fillets were used. These were immersed in a 6-percent brine solution for 5 minutes; drained; wrapped in vegetable parchment; and then steamed for 20 minutes. These cooked fillets were judged for quality by members of a selected taste panel, which consisted of 4 or 5 testers. Observations were made for appearance, flavor, texture, and odor. A low score for any one of the factors for the thawed or cooked fillets made them unacceptable. Whenever possible, each series of tests was repeated in the next day or two to determine the consistency of the organoleptic observations and to eliminate any possible gross error in sampling. Inasmuch as a fresh reference standard of each species could not be used for each test, frozen Pacific ocean perch (Sebastodes alutus) was used as the standard for comparison.



(ATLANTIC) OCEAN PERCH (SEBASTES MARINUS)

DISCUSSION

Each test was limited to representative samples of 3 or 4 species of rockfish and was repeated within a few days. Therefore, each series of tests after periodic intervals of storage required as much as two weeks to complete. It was not possible to make organoleptic examinations for all species after identical periods of cold storage. Since samples of some species were obtained at later dates, it was not possible to make all storage periods for any series of organoleptic examinations coincide. The general quality of the fillets after storage at 0° F. is summarized by 4-week periods in table 1.

Although samples of each species were usually examined at intervals of several weeks, often no definite changes in quality could be observed between any two consecutive examinations.

The summary of results that follows presents only those data in which the organoleptic observations showed a clear-cut change in the quality of the samples.

Pacific Ocean Perch (Sebastodes alutus)

Fillets of Pacific ocean perch had the best cold-storage keeping quality of all the Pacific Coast rockfish tested. The flavor and texture of the freshly-frozen fillets were excellent. After 15 weeks of storage, some fillets were lacking in flavor, and a few were discolored along the edges. After 25 weeks, the fillets were moderately discolored over-all and were somewhat rancid in flavor. After 32 weeks, the fillets were inedible.

Lobe-Jawed Rockfish (Sebastodes diploproa)

At the beginning of the test, the lobe-jawed rockfish fillets were rated about medium in appearance and flavor, and good in texture. After 12 weeks, the fillets were slightly discolored over-all, and a few samples were slightly rancid in flavor. After 20 weeks, the fillets were moderately discolored and moderately rancid in flavor. After 26 weeks, the fillets were inedible.

Bocaccio (Sebastodes paucispinis)

Bocaccio fillets were about equal in initial flavor to Pacific ocean perch but had a firmer and flakier texture. After 12 weeks of storage, the fillets were slightly tough but were still rated about equal in flavor to the Pacific ocean perch stored the same amount of time. After 19 weeks, the fillets were fairly good in appearance, flat to slightly rancid in flavor, and somewhat tough in texture. After 29 weeks, the fillets were inedible because of toughness. Also they were slightly darkened over-all, the light meat was flavorless, and the dark meat was rancid.

Chilipper (Sebastodes goodei)

Chilipepper fillets were found to be about equal in initial palatability to Pacific ocean perch and bocaccio and were rated very good. After 11 weeks in storage, the quality of the fillets had definitely dropped; all the samples showed a general discoloration and had toughened somewhat; and a few of the samples had a flat flavor while others had an off-flavor. After 17 weeks, the fillets were discolored, and some samples were rancid in flavor. After 22 weeks the fillets were all poor in quality because of rancidity and toughness.

Orange or Red Rockfish (Sebastodes pinniger)

Orange rockfish fillets were about equal to Pacific ocean perch in initial palatability. However, the appearance of the orange rockfish fillets deteriorated rapidly. After 12 weeks of storage, the fillets were discolored and rancid in odor but only slightly rancid in taste. After 16 weeks, the fillets were also rancid in taste and were only fair in over-all quality. After 22 weeks, the fillets were inedible.

Red Rockfish or "Red Snapper" (Sebastodes ruberrimus) 1/

At the beginning of the test, the red rockfish fillets were flaky in texture and slightly tough; however, the flavor was considered good. After 9 weeks of storage, the fillets had a slight over-all discoloration and a rancid odor. After 16 weeks the fillets were only fair in appearance and flavor. After 26 weeks, the fillets were inedible because of poor appearance and rancid flavor.

Vermilion Rockfish (Sebastodes miniatus)

In initial palatability, the vermilion rockfish fillets were rated good in flavor but were slightly tough. (Vermilion rockfish are usually discarded at sea because of the poor appearance of the skin, which is mottled with gray-black dots.) After three weeks of storage, the fillets were badly discolored and were rancid in flavor and odor. Because of this rapid deterioration in quality after storage, this species does not appear suitable for freezing.

Channel Rockfish or "Idiot" (Sebastolobus alascanus)

The first organoleptic test was made on the samples of channel rockfish after 15 weeks of storage, at which time the fillets were flat in taste and soft in texture. After 20 weeks, one sample was poor in flavor and mushy in texture, and the remaining samples were about medium in quality. After 28 weeks, all the fillets were rated inedible because of poor flavor and texture.

1/ FILLETS FROM THIS SPECIES OF FISH WERE NOT PREPARED IN THE USUAL COMMERCIAL MANNER BUT AS FOLLOWS: THE ROUND FISH WERE FROZEN AT SEA ABOARD SHIP. AT THE LABORATORY THE FROZEN FISH WERE THAWED AND FILLETED. THE FILLETS WERE THEN PACKAGED AND REFROZEN.

Ocean Perch (Atlantic) or Rosefish (*Sebastes marinus*)

In initial palatability, ocean perch (Atlantic) fillets was preferred over the other species of rockfish. However, there was not much difference in palatability between ocean perch and Pacific ocean perch. The difference was largely in texture, the ocean perch being somewhat more tender. After 12 weeks of storage and for the remainder of its storage life, the quality of the ocean perch (Atlantic) fillets were comparable to that of Pacific ocean perch fillets which had been in storage for the same length of time. After 13 weeks, a few of the ocean perch fillets were discolored along the edges and were lacking in flavor. After 25 weeks, some fillets were discolored over-all and were rancid in flavor along the edges. After 29 weeks, the fillets had a moderate over-all darkening, a discoloration along the edges, an accumulation of fat in patches, and a rancid flavor and odor. They were, therefore, considered inedible after this period of storage.

SUMMARY

Singles lots of various species of Pacific Coast rockfish fillets tested prior to freezing and storage at 0° F. differed in appearance, texture, or flavor. Pacific ocean perch (*Sebastodes alutus*), red rockfish (*Sebastodes pinniger*), bocaccio (*Sebastodes paucispinis*), and chilipepper (*Sebastodes goodei*) were rated very good. The group next in choice, rated good, consisted of red rockfish (*Sebastodes ruberrimus*), lobe-jawed rockfish (*Sebastodes diploproa*), vermilion rockfish (*Sebastodes miniatus*). No observation was made on the initial palatability of channel rockfish (*Sebastolobus alascanus*).

Pacific ocean perch fillets (*Sebastodes alutus*) had the best cold-storage keeping quality and the longest cold-storage life. Although bocaccio (*Sebastodes paucispinis*), fillets had a storage life about equally long, they did become tough. The cold-storage life for Pacific ocean perch fillets was 32 weeks and bocaccio 29 weeks. Vermilion rockfish (*Sebastodes miniatus*) deteriorated so rapidly in quality that they were not considered suitable for frozen storage. The other species of Pacific Coast rockfish fillets tested had a cold-storage life of 5 or 6 months.

Ocean perch (*Sebastes marinus*) fillets were given a slight preference over the Pacific Coast rockfish in initial palatability. The fillets were quite similiar to Pacific ocean perch (*Sebastodes alutus*) in appearance, flavor, and texture throughout most of the storage period. They had a cold-storage life of 29 weeks.

ACKNOWLEDGMENT

Clarence R. Lucas of the Market Development Section collected most of the samples used in this investigation and Miss Kathryn Osterhaug, Home Economist, of the Educational and Market Development Section assisted in conducting the organoleptic tests. Both of these sections are part of the Service's Branch of Commercial Fisheries.

FREEZING AND COLD STORAGE OF PACIFIC NORTHWEST FISH AND SHELLFISH
PART II - KING CRAB

By Martin Heerdt, Jr.* and John A. Dassow**

ABSTRACT

VARIOUS METHODS OF PACKAGING ALASKAN KING-CRAB MEAT WERE STUDIED TO DETERMINE PROCEDURES THAT WOULD YIELD MAXIMUM FROZEN-STORAGE LIFE OF THE MEAT. THE RESULTS INDICATE THAT FROZEN KING-CRAB MEAT CAN BE STORED SATISFACTORILY AT 0° F. FOR AS LONG AS ONE YEAR IF PACKAGED IN HERMETICALLY SEALED TIN CONTAINERS OR NINE MONTHS IF PACKAGED IN (MSAT) CELLOPHANE.

BACKGROUND

King crab (Paralithodes camtschatica) were caught and processed by the Japanese and the Russians as long ago as the early nineteen hundreds, but were not handled in commercial quantities by United States fishermen until the past few years. In 1941 the U. S. Fish and Wildlife Service conducted exploratory fishing to determine where in Alaskan waters the king crab could be caught in commercial quantities. Application of these findings by the American fishing industry was delayed by World War II, but since 1945 a number of concerns have entered actively into the field. Nearly all the American-caught and processed king crab has been frozen rather than canned, which is the reverse of the practice of the Japanese and the Russian packers. Production of canned crab meat requires a larger crew of workers and more equipment aboard the crab-processing ship than does the processing of frozen crab.

Until recently (Dassow 1950), no technical information has been available on the most suitable methods of freezing and storing king crab. However, several possible methods of processing were available for consideration. The raw or the cooked crab legs could be frozen in the shell and ice-glazed to prevent dehydration, or the raw crab legs could be cooked and the meat removed from the shell and packaged in a number of different ways. As another alternative, the cooked crab legs could be frozen in the shell and ice-glazed, then thawed later, the meat removed from the shell and packaged for refreezing. Packaging materials could include flexible films, such as cellophane and either friction-top or hermetically-sealed tin containers. If packed in tin containers, the crab meat could be covered with a weak brine solution. This report presents data on the cold-storage keeping quality of crab meat processed and packaged by some of the foregoing methods.

EXPERIMENTAL

Background information for the present work was obtained from preliminary storage tests of samples prepared aboard the trawler Alaska, which fished for king crab in the Bering Sea during August 1947. Practical aspects of this fishing venture are described in Fishery Leaflet 330 (King 1949). The samples for the present study were prepared by U. S. Fish and Wildlife Service personnel in May and June of 1948 aboard the factoryship Pacific Explorer. A report on the operations of the Pacific Explorer in the Bering Sea is presented in Fishery Leaflet 361 (Wigutoff and Carlson 1950).

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King crab for the storage studies were obtained by chartered vessels during commercial crab-trawling operations in 30 to 40 fathoms of water in the area north and somewhat east of Amak Island on the Bering Sea side of the Alaska Peninsula during May and June of 1948. Only select live crabs were used. These were processed entirely by the laboratory personnel on the same day that they were caught. Butchering or "backing" (removal of the carapace) was accomplished by impaling the animal on the jointed hook of the butchering tool and pulling it down sharply on the horizontal blade (fig. 1). This served also to divide the crab into two halves, each consisting of a claw and three legs. Gills and viscera were then cut or pulled away and the halves were washed in clean, cold, running sea water.

FIG. 1 - THE BUTCHERING OPERATION. THE FIXED BUTCHERING TOOLS ARE TO THE LEFT OF THE CONVEYOR.

At this stage, a number of raw legs with attached body segments were selected at random for freezing, glazing, packing, and storing. The remaining crab sections were cooked in a 30-gallon vat of boiling water for approximately 15 to 18 minutes and then cooled immediately by dipping into cold sea water.

A number of cooked legs with attached body segments were also taken at random for freezing, glazing, and storing. The meat in the remaining cooked sections was removed by breaking and tearing the legs apart at the joint and shaking the meat from the shell (fig. 2). The leg meat was placed in separate shallow trays (experience indicated that baskets would have been better) and washed in clean, running sea water with sufficiently rapid agitation to remove adhering coagulated proteinaceous material and blood, bits of shell, pieces of gills, tendon, and visceral material (fig. 3). After being washed and inspected, the meat was allowed to drain completely before packing (fig. 4). The methods used in preparing test samples are described in table 1.

FIG. 2 - THE SHAKING TABLE. THE CRAB MEAT IS REMOVED FROM A LEG SEGMENT BY A QUICK, SHARP RAP OF THE HAND ON A BRACKET COVERED WITH SPONGE RUBBER.

Due to the limitations at sea, all samples were prepared by vessel personnel and were not prepared at the same time but rather were prepared during an interval of several weeks during the voyage. All the samples had been frozen at least six weeks when the vessel returned to port. On arrival at Seattle, the samples were transferred to the Fish and Wildlife Service cold-storage room and stored at 0° F. Since laboratory personnel

were not aboard the vessel while at sea, the initial examinations were delayed for a number of weeks. This accounts for the lack of data during the early period of storage.

FIG. 3 - WASHING STATIONS. THE PANS OF MEAT ARE WASHED IN RUNNING SEA WATER IN STAINLESS STEEL SINKS.

FIG. 4 - PACKING TABLE.

Table 1 - Preparation of test samples. (All samples were frozen at -20° F. to -30° F. in a blast freezer, then stored at 0° F.)

Sample	Sample Material	Packaging Method
a	Cooked, dressed, half crab portions, in the shell.	Half crabs, water-ice glazed, and packed into untreated fiberboard cartons, holding about 25 pounds.
b	Crab meat, picked from body and leg sections after cooking.	One pound quantities of meat wrapped in (MSAT)1/ cellophane and five of these packages placed in a waxed carton.
c	Crab meat, picked from body and leg sections after cooking.	Meat packed in No. 2 (307x409) inside "C" enameled cans and hermetically sealed.2/
d	Crab meat, picked from the first or large leg section (the leg section nearest the carapace) after cooking.	Meat packed in No. 2 (307x409) inside "C" enameled cans and hermetically sealed.
e	Crab meat, picked from the second and third leg sections after cooking.	Meat packed in No. 2 (307x409) inside "C" enameled cans and hermetically sealed.
f	Crab meat derived from body and leg sections that had been cooked, frozen in the shell, and stored at 5° F. for a period of one month prior to thawing and picking.	Meat packed in No. 2 (307x409) inside "C" enameled cans and hermetically sealed.
g	Crab meat, picked from body and leg sections after cooking.	Meat packed in No. 2 (307x409) inside "C" enameled cans, covered with 50 ml. of one-percent salt solution and hermetically sealed.
h	Crab meat, picked from body and leg sections after cooking.	Meat packed in No. 2 (307x409) inside "C" enameled cans covered with 50 ml. of 3-percent salt solution and hermetically sealed.

1/ (MSAT), MOISTURE-VAPOR-RESISTANT, HEAT SEALING, ANCHORED COATING, TRANSPARENT CELLOPHANE.
2/ ALL CANS WERE DOUBLE SEAMED AT ATMOSPHERIC PRESSURE.

For evaluation of quality, samples were removed from cold storage at various intervals and thawed in circulating air at room temperature before being opened. All samples were judged for appearance (color) and flavor on the basis of the following terminology and numerical ratings:

Appearance

Color Value	Rating
No discoloration	5
Slight discoloration	4
Moderate discoloration	3
Considerable discoloration .	2
Extreme discoloration	1

Flavor

Flavor Value	Rating
Normal - no off-flavor	5
Slight off-flavor	4
Moderate off-flavor	3
Definite off-flavor	2
Inedible	1

Fractional values were used to indicate quality ratings falling between the whole numbers. The data as reported are an average of at least six tenderometer readings and six taste-panel observations. Samples receiving an average color or flavor rating of less than 3.0 were not considered salable. Not more than three samples were evaluated at any one time in order to eliminate the fatigue factor in organoleptic testing.

Tenderness is one of the qualities of frozen crab meat most subject to change. Relative values of tenderness were obtained by means of a tenderometer (Shockey, McKee, and Hamm 1944). Any sample of crab meat having an average tenderometer value of 36 or above was not considered salable.

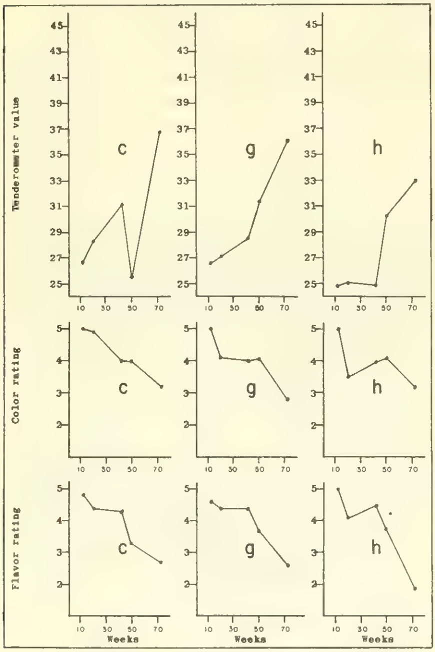

FIG. 5 - EFFECT OF STORING FROZEN KING-CRAB MEAT PACKED IN TIN: DRY (C); IN 1-PERCENT BRINE (G); AND IN 3-PERCENT BRINE (H).

DISCUSSION

Examination of the crab meat frozen in tin containers--dry (c), with added one-percent salt solution (g), and with added three-percent salt solution (h)--revealed that the samples were not always as uniform as might be desired (fig. 5). Specifically, the low color and flavor values recorded at 20 weeks for crab meat in a three-percent salt solution (h) and the low tenderometer value recorded at 50 weeks for dry crab meat (c) are indicative of a fair amount of variation within identical samples. Judging from the data that was obtained, however, the three-percent salt-solution pack remained somewhat more tender throughout the entire storage period than either the one-percent salt-solution pack or the dry pack. Otherwise, the addition of salt solutions did not appear to have any appreciable effect upon either color or flavor. The storage life of all three packs was approximately 60 weeks at 0° F. These acceptability limits resulted from alterations in flavor before texture or color changes had reached a critical stage.

Cellophane packs (b) were equal to tinned packs (c) in retention of color, according to data in figure 6. Tinned packs were somewhat better in flavor retention than cellophane packs during the early examinations, but there was no flavor difference between the packs at the final (72 weeks) examination. Frozen king-crab meat packed in tin was definitely superior in texture to the cellophane packs. In fact, the tinned pack stored at 0° F. remained commercially acceptable until about the 58th week when it failed on the basis of both color and flavor. The cellophane pack, in contrast reached the limit of acceptability at about 44 weeks because of high tenderometer values and poor flavor. (Frozen Dungeness-crab meat when packed in cellophane bags reached its limit of commercial acceptability due to toughening in less than 13 weeks, Heerdt 1947). King-crab meat has frozen-storage characteristics definitely superior to Dungeness-crab meat.

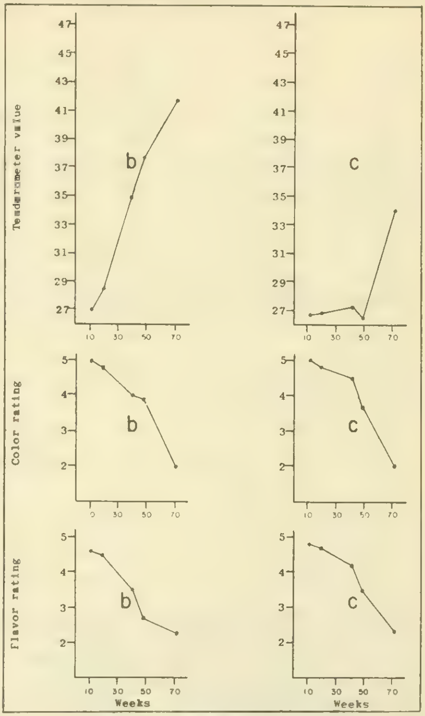

FIG. 6 - EFFECT OF STORING FROZEN KING-CRAB MEAT: PACKAGED IN (MSAT) CELLOPHANE (B), AND PACKED IN TIN (C).

Figure 7 shows the effect of storing frozen cooked whole king-crab legs in the shell (a), picked meat from the large segment of the legs packed in tin containers (d), and picked meat from the two smaller segments of the legs packed in tin containers (e). On the basis of tenderometer values, the large-leg segment pack was somewhat superior to the small-leg segment pack in keeping quality. Both the large- and small-segment packs in tin were definitely superior on the basis of color, flavor, and tenderometer values, to cooked whole legs frozen and stored in the shell. The whole legs (a) reached the limit of commercial acceptability at about 46 weeks because of high tenderometer values and poor flavor, whereas the picked meat (d) and (e) from both the large and small segments remained acceptable up to about 66 weeks at 0° F. Picked-meat packs (d) and (e) fell below the limits of acceptability at 66 weeks because of both poor color and poor flavor.

The effect of storage at 0° F. on king-crab meat prepared from cooked crab legs that were held frozen in the shell for one month, then thawed, picked, packed in tin containers, and refrozen (f) is given in figure 8. The effect of storage at 0° F. on king-crab meat prepared from cooked crab legs from which the meat was picked immediately, packed into tin containers, and frozen (c) is also given in figure 8. The purpose of pack (c) was to serve as control for pack (f).

Pack (c) was only slightly superior in color and flavor, yet definitely superior in tenderness. In fact, the refrozen pack fell below commercial acceptability after only 21 weeks of storage because of high tenderometer values. Pack (c), however, remained commercially acceptable until sometime between the 50th and 72nd week when it declined below the acceptable limit because of changes in flavor. By this time both the flavor and color of the refrozen pack also scored less than

3.0. Variation in quality within identical samples was of minor importance. Thus, refreezing king-crab meat that has been cooked and stored frozen in the shell is of limited practicability.

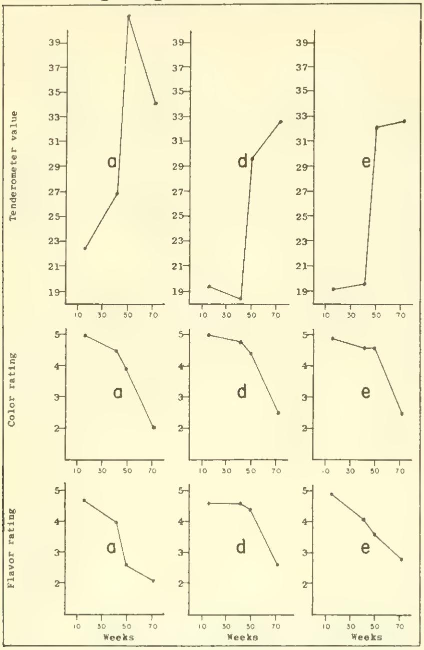

FIG. 7 - EFFECT OF STORING FROZEN COOKED KING CRAB: WHOLE LEGS IN THE SHELL (A), PICKED MEAT FROM THE LARGE SEGMENT OF THE LEGS PACKED IN TIN CONTAINERS (D), AND PICKED MEAT FROM THE TWO SMALLER SEGMENTS OF THE LEGS PACKED IN TIN CONTAINERS (E).

Crab meat wrapped in (MSAT) cellophane and stored at 0° F. remained palatable for nine months before becoming undesirably tough. Cooked crab legs that had been frozen, ice-glazed, packed in untreated fiberboard cartons, and stored at 0° F. also remained palatable for nine months. Flavor and color were not limiting factors for either of these two methods of packaging.

Crab meat packaged in hermetically-sealed tin containers and stored at 0° F. was palatable for twelve months. Covering the crab meat with 1-percent or 3-percent salt solution prior to sealing the tin containers delayed the onset of toughening but did not extend storage life beyond the twelve-month period because off-flavors developed.

SUMMARY

King crabs obtained by trawling near Amak Island in the Bering Sea were butchered, cooked, packaged by various methods, frozen, and stored temporarily aboard a mothership. At port, the pack was transferred to frozen storage ashore. Samples were then withdrawn at intervals and judged as to color, flavor, and texture. Color and flavor were determined organoleptically; texture was determined by means of a tenderometer. The studies indicate that king-crab meat has good storage characteristics when held at 0° F.

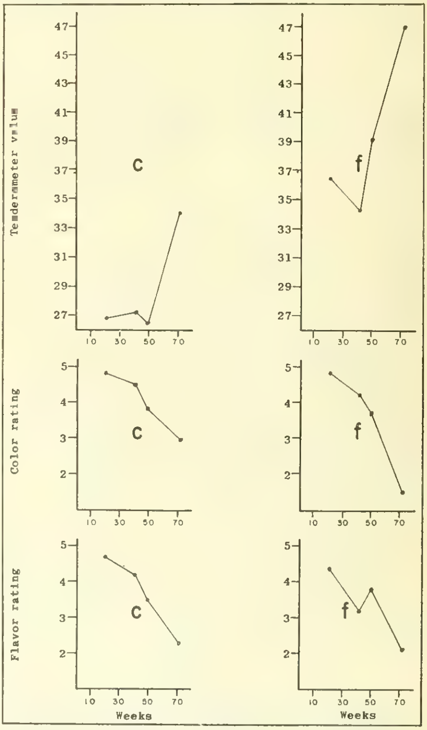

FIG. 8 - EFFECT OF STORING FROZEN KING-CRAB MEAT (C), AND REFROZEN KING-CRAB MEAT (F): BOTH PACKED IN TIN.

Refreezing meat removed from cooked crab that had been frozen and stored in the shell for one month at 0^{o} F. gave an undesirably tough product after four-months' storage.

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BIBLIOGRAPHY OF THE PRESERVATION OF FISHERY PRODUCTS BY FREEZING

Fishery Leaflet 265, Bibliography of the Preservation of Fishery Products by Freezing, contains references on the freezing of fishery products as far back as 1898 and covers the subject quite thoroughly from about 1920 to December 1947, inclusive. This 87-page bibliography contains articles from many journals and books. In the majority of cases the original article was procured. To make the bibliography more valuable, a brief summary of each article is included.

Divided into two parts, Part I covers the period to January 1945 and is a reissue; and Part II covers the period of January 1945 to December 1947, inclusive, and has been issued as a supplement. Those who already have Part I, can obtain only Part II to complete the leaflet, while others can obtain both parts.

This is the final issue of this bibliography. More recent literature in the field of frozen fishery products is covered in the Service's publication, Commercial Fisheries Abstracts.

TECHNICAL NOTE NO. 22--A NEW LIQUID MEDIUM FOR FREEZING ROUND FISH

INTRODUCTION

As one phase of the project dealing with the freezing of fish at sea now being conducted by the Boston Laboratory of the U. S. Fish and Wildlife Service, commercially-important New England species of groundfish (cod, haddock, and ocean perch) are being frozen at sea "in the round," that is ungutted, on board the experimental trawler Delaware for later processing into frozen fillets ashore. The fish, immediately after removal from the trawl, are frozen by immersion (Magnusson, H. W.; Pottinger, S. R.; and Hartshorne, J. C., 1952) in a strong sodium-chloride (23 percent by weight) brine maintained, as nearly as possible, at a temperature of 5° F. (-15° C.). The fish are then stored in the vessel's cold-storage compartments at 0° to 5° F. (-17.7° to -15° C.) until the trawler returns to port.

Subsequent experience on the Delaware indicates that although sodium-chloride brine is a good immersion-freezing medium it imposes two limitations on operations of freezing fish at sea: (1) restriction of the freezing operation range from 5° to 10° F. (-15° to -12.5° C.) with the concentration of brine used to avoid freezing-out of water or precipitation of salt in the tubes of the heat-exchanger in the refrigerating system, and (2) rises in temperature above the safe maximum (about 10° F.) for negligible penetration of the salt into the meat of the fish when gluts of fish are being frozen.

Immersion freezing utilizes the relationship between the concentration and freezing point of a solution. Water, which normally freezes at 32° F. (0° C.), freezes at a lower temperature if a soluble substance is added to it. Since the degree of depression of the freezing point of a solution is related to the concentration of the substance added, a strongly concentrated solution may freeze at temperatures well below 0° F. (-17.7° C.). Refrigeration of such solutions results in formation of a cold bath or immersion-freezing medium. Immersion of a relatively warm object in the solution causes a rapid flow of heat from the object to the cold solution. The intimate over-all contact and large temperature differential enables freezing of the object to be accomplished in a fraction of the time necessary for other methods of freezing.

Foods may be successfully frozen in such freezing baths if the soluble substance added to the water is carefully chosen. Brines composed of sodium chloride and sugar (Goldsmith and Bartlett 1948) have been proposed for the freezing of meats. Sugar syrups (Taylor and Ferris 1939; Bartlett 1941 and 1942; Woodroof 1939) are used in the freezing of fruits and vegetables. Sodium-chloride brine has long been advocated as a liquid medium for the freezing of fish (Ottesen 1915 and 1925).

Ideally, an immersion-freezing medium designed to be used for freezing fish at sea should have the following characteristics. It should:

1. Remain liquid below 0° F. and allow freezing operations at or below that temperature.

2. Produce no adverse effect on the frozen product.

3. Exhibit high specific heat and thermal conductivity.

4. Have a low viscosity.

5. Be relatively inexpensive and easy to reclaim and re-use.

6. Exhibit a progressive decrease in freezing point with increase in concentration, that is, should evidence a straight-line relationship when concentration is graphed against freezing point.

A search of the literature did not yield information on a liquid medium that entirely suited the particular needs of the freezing-fish-at-sea project. Brines or syrups used industrially for freezing of foods other than fish are maintained at or slightly above 0° F. (-17.7° C.). Moreover, the products to be frozen are, in general, uniform in size and shape and the rate at which they are delivered to the freezer is regulated. Under such ideal conditions, few gluts occur and temperature variations in the freezing media are minimized. There has been, until the present, little incentive and need for research and development of better liquid-freezing media which could be adapted to the freezing of fish.

EXPERIMENTAL

During the past year, as a part of the freezing-fish-at-sea project, a large number of chemical compounds, organic and inorganic, alone or in combinations, were tested at this laboratory as possible materials for new liquid-freezing media. The great majority of these materials were rejected from further consideration for reasons of high cost, toxicity, penetration into the meat of the fish, or high viscosity. Research then centered around those showing the most promise, such as a few inorganic and organic salts, alcohols, glycerols, glycols, and various sugars. Combinations of sugars with inorganic salts for reasons of cost, availability, and lack of toxicity appeared to be best.

Goldsmith and Bartlett (1948) reported on media containing mixtures of the sugars (glucose and sucrose, and of glucose, sucrose) and sodium chloride. They showed that both of these media evidence a straight-line relationship between concentration and freezing point. These media were tested in the routine manner in this laboratory. They were all characterized by high (40 to 60 percent by weight) sugar content and high viscosities.

To lessen the viscosity and to reduce the expense of the above media, the sodium chloride content was raised from the recommended 3 percent to about 12 percent and the glucose and sucrose contents were reduced, respectively, to about 34 and 3 percent (by weight). At these concentrations the medium was capable of remaining fluid at a temperature of -10° F. (-23.3° C.). By using such a solution, the freezing operation range could be extended by only 2° F. while operating 13° F. above the freezing point as a safety factor. Though an improvement, such a small extension of the operating temperature range over that of sodium-chloride brines could not justify the use of relatively expensive sugar.

There are, however, several other features of such sugar-sodium chloride mixtures which recommend them. The first is the enhanced appearance of the frozen product due to a glistening sugar glaze left upon it. The second is the markedly lower salt penetration into the round fish during freezing due, apparently, to the two factors of the lowered temperature and decreased (as compared to a 23 percent sodium-chloride brine) salt concentration. Finally, there appears to be formed at low temperatures what Noyes (1940) reported to be "double-compounds" of the glucose and sodium chloride which render the medium only very slightly sweet. These "double-compounds" may also be a factor in reducing salt penetration of the flesh by osmosis.

Calcium-chloride solutions, of varied concentrations, had previously been tested as possible freezing media. The high solubility of calcium chloride and its extreme range of freezing-point depression (to -59.8° F. or -51° C.) made it a very desirable component of a freezing solution. As the single component, other than water, of a freezing medium, it had caused very noticeable deterioration of the surface membrane of the fish. In combination with sodium chloride, the solubility of each was limited and the maximum added depression of the freezing-point of the mixed brine was only about 3° to 4° F.

The experiments had indicated that calcium chloride, in a concentrated solution, is more than twice as effective per chemical-unit weight in reducing the freezing-point of water as is sodium chloride. It was reasoned that substitution, in whole or in part, of calcium chloride for sodium chloride in the above mentioned sugar-sodium chloride solution might result in a medium requiring less glucose, no sucrose, evidencing little or none of the typical calcium chloride surface effect on the fish and yet capable of attaining a much lower freezing temperature. All these suppositions were upheld by subsequent experimentation. Furthermore, calcium chloride, while dissolving, gives off much heat. The heat raises the temperature of the liquid and greatly facilitates the subsequent solution of glucose.

A series of experiments were performed to determine the minimum proportions of glucose to calcium chloride necessary to prevent the deteriorative effect of the calcium chloride on the surface membrane of the fish. The composition of the solution was varied radically. It was found that a minimum of one part glucose to one part calcium chloride was necessary. With decreasing quantities of glucose, the adverse effect on the surface of the fish became more and more apparent. Increase of the glucose content to or beyond the 1:1 ratio completely eliminated the surface effect.

Fish were frozen in an unagitated bath consisting of 34 percent glucose and 20 percent calcium chloride, in water, at a temperature of -20° F. (-28.8° C.). Visual and organoleptic testing of the fish failed to reveal any adverse effects. When subsequently stored in a plate-freezer (-50° F. on the plates and about -30° F. in the ambient air) a wholly transparent and apparently durable glaze was formed which greatly enhanced the appearance of the fish. Woodroof (1939), in referring to such glazes on fruits, reports them to be of two millimeters in thickness and apparently unchanged after six months of storage.

Although the refrigerating capacity of the compressor serving the immersion-freezer at the laboratory was highly inadequate for operations at temperatures approaching -20° F. (-28.8° C.), it was decided anyway, to attempt some preliminary studies of freezing rates of fish in the medium. A solution, consisting of 25 percent each (by weight) of calcium chloride and glucose was prepared. These concentrations were selected since they appeared in small-scale tests to afford a solution which satisfied the requirements previously listed for a medium for use in freezing fish at sea. The solution freezes at a temperature of about -24° F. (-31.1° C.). It has a low viscosity and is the least expensive. It affords ample excess of dissolved calcium chloride and glucose to eliminate concern over freezing out of the medium due to dilution of the brine. Such dilution occurs when large quantities of fish, carrying considerable adsorbed water, are placed in the medium to be frozen.

The temperature of the medium, in an open tank refrigerated by direct expansion of a gas in surrounding coils, was reduced to about -18° F. (-27.8° C.). Since the capacity of the compressor was inadequate to maintain this temperature and, at the same time, absorb the heat released to the solution by a pump used to

circulate and agitate the medium, it was necessary to study the freezing rates in still brine. Scrod haddock (3 pounds in weight and about $2\frac{1}{2}$ inches in cross-section at the widest point) were frozen in a period of 40 to 45 minutes. Large-size haddock (5 pounds in weight and 3 to 4 inches wide) required 90 minutes to freeze. Magnusson and Hartshorne (1952), reporting on rates of freezing of scrod and large haddock at 0° F. (-17.7° C.), found them to be, respectively, 80 and 110 minutes in agitated brine. The rates at 10° F. (-12.5° C.) in agitated brine were reported to be, respectively, 125 minutes and 170 minutes.

Metal corrosion, somewhat of a problem with sodium-chloride brines, is lessened in calcium-chloride brines and should be still less of a problem due to the anti-corrosive effect of sugar.

Taste-panel members, when served portions of unseasoned, steamed fish, previously frozen in the glucose-calcium chloride medium, were unable to distinguish between them and control samples of fish frozen in sodium-chloride brine.

Fish, from both lots, were then stored for one week in a household refrigerator (about 40° F.) and again served, after steaming, to the taste panel. Other than the normal decline in quality for both lots, no adverse comments were made by the panel. Fish, identically frozen in the experimental medium but differing in that some were air-thawed and the others water-thawed, when served as before to the taste panel, were judged to be of good quality and indistinguishable one from the other. It is apparent that, under laboratory conditions, the quality of the fish is not affected by immersion-freezing in the new medium. As a test for the development of off-flavors over an extended period of storage, several hundred pounds of fish frozen in this medium will be placed in a commercial cold storage and sampled at regular intervals.

DISCUSSION

It would seem that the limitations imposed upon the freezing-fish-at-sea project might be overcome by the use of sugar-calcium chloride brine. Since there is a progressive decrease in freezing point with increasing concentration, the effective freezing temperature of the medium may be extended from a range of about 5° to 10° F. (-15° to -12.5° C.) to a range of from -18° to +10° F. (-17.5° to -12.5° C.)--an increase of at least 23 degrees F. Such an extended range would render unimportant any temporary increase in temperature of the medium due to large loads of fish. Further, dilution of the brine by water adsorbed on the surface of immersed fish would no longer be a source of concern since, due to the high concentration, the effect of dilution on the freezing-point depression would be very slight. The necessity for constant supervision of the machinery would be eliminated.

Rates of freezing of fish, due to the lower temperatures attainable in the new medium, were faster than in sodium-chloride brines during the preliminary studies. The resultant shorter immersion period necessary for freezing the fish has, at least, a theoretical advantage in the preservation of quality.

Penetration of the calcium chloride into the meat of the fish should be minimized by the rapidity of freezing of the outer layer of meat, by the apparent formation of the "double-compounds" of salt and sugar with resultant decrease in quantity of salt subject to osmosis, and by the shortened immersion periods. Tests, so far performed, have indicated this to be the case.

SUMMARY

It is felt that an immersion-freezing solution peculiarly well adapted to the requirements of freezing fish at sea may have been developed.

The straight-line relationship between concentration and freezing point appears to insure safer operating conditions without need for constant attention.

Freezing rates were faster than in sodium-chloride brines in the tests so far performed, due to the lower temperatures attained.

Temperature increases in the freezing medium, induced by gluts of fish, should not be of such magnitude as to rise above the desired freezing temperature maximum of 10° F. (-12.5° C.). The freezing-operation range has been extended from a temperature range of 5° F. to 10° F. to a range -18° F. to +10° F.

No adverse effects on the frozen product were noted during organoleptic testing of fish frozen in the medium.

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--John A. Holston, Chemist,
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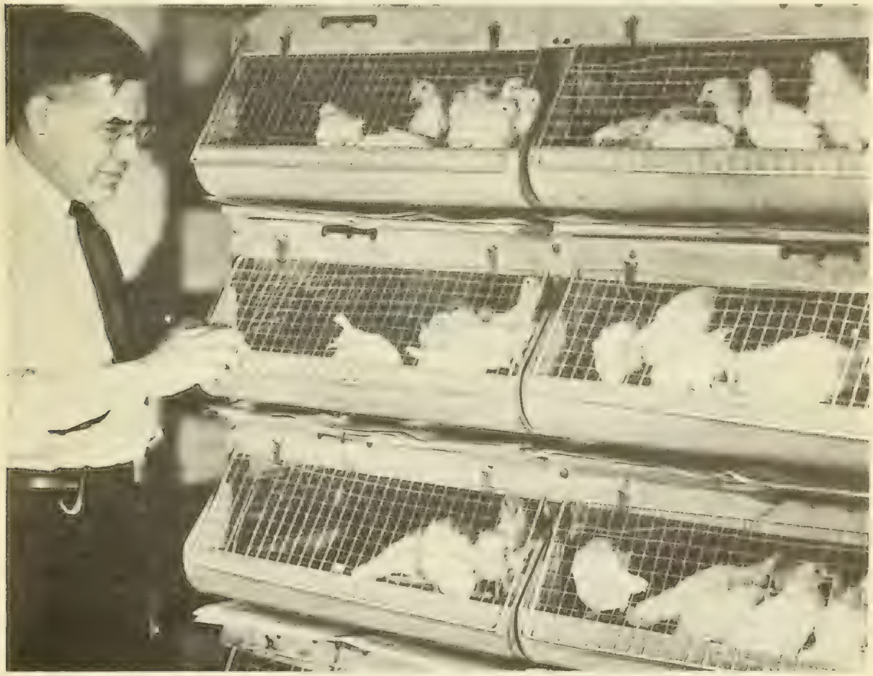
TECHNICAL NOTE NO. 23 - FEEDING FISH MEALS AND SOLUBLES TO CHICKENS DOES NOT AFFECT FLAVOR OF MEAT

Previous tests conducted at the Fishery Technological Laboratory at College Park, Maryland, have shown that feeding chickens, turkeys, and ducks diets containing as much as 30-percent fish meal did not cause off-flavors in the meat. No previous work had been done with condensed fish solubles.



NO OFF-FLAVORS DEVELOPED IN THE MEAT OF WHITE LEGHORN CHICKS FED DIETS CONTAINING FISH MEALS AND SOLUBLES.

Early in February, 15 white Leghorn chicks (which had been on a four-week assay of the vitamin B_{12} content of various condensed fish solubles) were fed the following diet: About 10 percent menhaden fish meal, 13 percent condensed menhaden fish solubles, 7 percent alfalfa meal, and 70 percent ground yellow corn meal (percentages all based on weight). This is not a diet to be recommended for raising chickens, but it should permit evaluating the fishery products in respect to producing off-flavors in the meat.

After feeding this diet to the birds 4 to 8 weeks, they were butchered and dressed. The dressed birds were distributed to various staff members for cooking and taste-testing. This method was used because each individual could prepare the birds according to his favorite recipe. The tester would thus be familiar with the desirable flavor expected and could more easily detect any off-flavors. Only one

person thought he could detect a fishy flavor but he was not sure of it. The others reported the flavor and texture of the meat to be excellent.

On May 7, 16 white Leghorn chicks (which had been on a five-week test to determine the nutritive value of the protein of a series of fish meals and condensed fish solubles) were fed the following diet: About 20 percent condensed menhaden solubles, 3 percent alfalfa meal, 1 percent cod-liver oil, and 76 percent ground yellow corn meal (percentages all based on weight). Growth was rather slow, otherwise the birds seemed to fatten nicely. Between June 1 and June 30, the birds were butchered and dressed, and distributed to the various testers who again cooked and prepared the birds according to their favorite recipes. All of the people reported the flavor and texture of the meat to be excellent.

These short-time studies indicate that the meals and condensed fish solubles which were tested (all of them were low in oil) did not produce any distinct off-flavors in the meat of chickens.

--Hugo W. Nilson, Pharmacologist in Charge,
Fishery Technological Laboratory,
Branch of Commercial Fisheries,
U. S. Fish and Wildlife Service,
College Park, Maryland.

UTILIZATION OF FISHERY BYPRODUCTS IN WASHINGTON AND OREGON

The status of the fishery byproducts industry in Washington and Oregon is discussed in Fishery Leaflet 370, *Utilization of Fishery By-Products in Washington and Oregon*, by F. Bruce Sanford.

This 24-page publication describes the utilization of the fish waste which is utilized as whole waste or is separated into its various components and selected portions utilized. The whole waste is used in fish hatcheries, on fur farms, in pet food, and in reduction plants. The selected portions used are the skins, eggs, and livers and viscera. The skins are processed for manufacture into leather for women's shoes; the eggs are made into caviar and fish bait; and the livers and viscera are rendered for oil and vitamin A.

Various producing areas in the two States are pointed out in this leaflet. It indicates that the most important in Washington are Puget Sound, Grays Harbor, Columbia River, and Willapa Harbor. In Oregon, the Astoria-Warrenton-Hammond area is the center of greatest production; also important are Yaquina Bay, Coos Bay, and Tillamook Bay.

Free copies of Fishery Leaflet 370 are available upon request from the Division of Information, U. S. Fish and Wildlife Service, Washington 25, D. C.

TECHNOLOGICAL PUBLICATIONS, FISCAL YEAR 1951-52

COMMERCIAL FISHERIES REVIEW Articles and Separates

The following technological articles appeared in Commercial Fisheries Review and were also issued as separates. Both the issue in which each article appeared and the number of the separate which was issued after the article was published in the Review are given below.

Effect of Ascorbic Acid on Keeping Quality of Frozen Oysters, by S. R. Pottinger, vol. 13, no. 7, July 1951, pp. 5-8 (Sep. 287).

Results of Some Tests with Frozen Oysters, by S. R. Pottinger, vol. 13, no. 10, October 1951, pp. 1-5 (Sep. 290).

A Study of pH of Strictly Fresh Commercially-Shucked Eastern Oysters, by S. R. Pottinger, vol. 13, no. 11a, November 1951, pp. 8-10 (Sep. 295).

Chemistry of Menhaden, by C. F. Lee, vol. 13, no. 11a, November 1951, pp. 11-19 (Sep. 296).

Cytological Studies on Lactobacillus leichmannii in the Assay of Vitamin B_{12}, by Sigurdur H. Petursson, vol. 13, no. 11a, November 1951, pp. 20-25 (Sep. 297).

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Suggested Code for Fish Meal, Technical Note No. 12, by F. Bruce Sanford, vol. 13, no. 11a, November 1951, pp. 34-35 (Sep. 299).

Acceptability and Keeping Quality of Pacific Ocean Perch Fillets, Technical Note No. 13, by M. E. Stansby, vol. 13, no. 11a, November 1951 (Sep. 300).

A Brief Study of the Alkali Process for Recovery of Oil from Pink Salmon Cannery Waste, Technical Note No. 14, by R. N. Ten Eyck, H. W. Magnusson, and J. E. Bjork, vol. 13, no. 11a, November 1951, pp. 39-43 (Sep. 301).

Conducting Organoleptic Tests in the Laboratory, Technical Note No. 15, by M. E. Stansby, vol. 13, no. 11a, November 1951, pp. 44-46 (Sep. 302).

A Simple Penetrometer for the Measurement of Texture Changes in Canned Salmon, Technical Note No. 16, by H. J. Craven and John A. Dassow, vol. 14, no. 1, January 1952, pp. 18-21 (Sep. 305).

Freezing Fish at Sea--New England, vol. 14, no. 2, February 1952 (Sep. 306):
Part I - Preliminary Experiments, by Jean C. Hartshorne and Joseph F. Puncochar, pp. 1-7.
Part II - Experimental Procedures and Equipment, by H. W. Magnusson, S. R. Pottinger, and J. C. Hartshorne, pp. 8-15.
Part III - The Experimental Trawler Delaware and Shore Facilities, by C. Butler, J. F. Puncochar, and B. O. Knake, pp. 16-25.
Part IV - Commercial Processing of Brine-Frozen Fish, by C. Butler and H. W. Magnusson, pp. 26-29.

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Frozen Atlantic Oyster Investigations, by S. R. Pottinger, Food Technology, vol. 6, no. 1, January 1952, pp. 28-30.

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MILD CURING, PICKLING, DRY SALTING, AND SMOKING SALMON

Mild-cured salmon is a lightly salted product which is largely dependent on refrigeration for preservation. This method of curing was first introduced on the Pacific Coast in 1889 when a shipment was prepared for the German market, but the experiment was unsuccessful. Salmon was not mild-cured in large quantities until 1898, when two small plants were established on the Columbia River. Packing of mild-cured salmon began on Puget Sound in 1901. While a few tierces were occasionally packed in Alaska prior to 1906, it was not until then that mild-curing was established on a commercial basis. A substantial part of the king salmon taken in southeastern Alaska is now mild-cured.

Mild-cured salmon must be handled more carefully than any other salmon product. In few food products is handling so important in determining the quality of the manufactured product. Red king salmon is used almost exclusively, and dressed fish weighing 18 to 20 pounds are the smallest sizes suitable for mild-curing. There is some variation in this minimum, as at Astoria, Oregon, fish of less than 30 pounds in weight are rejected by mild-curers, while in Vancouver, Canada, the minimum size is 18 pounds (dressed weight).

The following illustrations show the steps in the preparation of salmon for mild-curing:

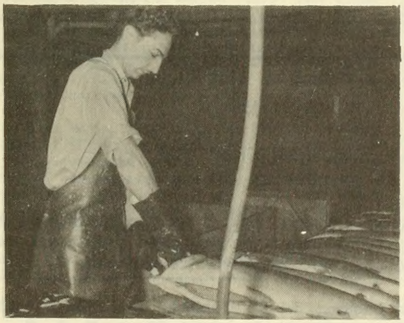

FIG. 1 - REMOVING THE HEAD FROM KING SALMON PRIOR TO SPLITTING THE FISH.

FIG. 2 - SPLITTING KING SALMON

FIG. 3 - CLEANING AND TRIMMING KING SALMON SIDES.

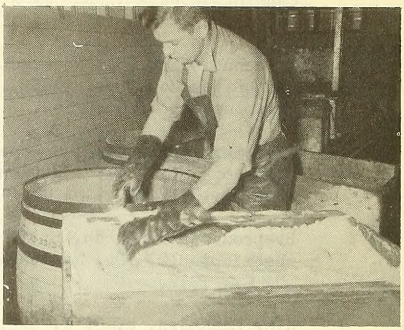

FIG. 4 - SALTING KING SALMON SIDES.

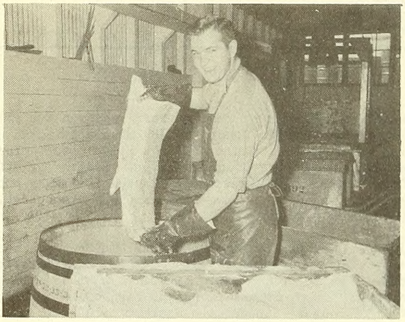

FIG. 5 - PLACING SALTED SIDES OF KING SALMON INTO TIERCE FOR CURING.

FIG. 6 - FILLING TIERCE WITH KING SALMON SIDES FOR MILD CURING.

By Norman D. Jarvis --Fishery Leaflet 60

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INT.-DUP. SEC., WASH., D.C. 32913

ODOR CONTROL IN FISH-PROCESSING PLANTS

CONDITIONS EXISTING AROUND MODERN FISH INDUSTRIES IN THE UNITED STATES: As in other industries, the conditions existing around fish-processing plants in the United States depend on both management and the type of operation. In plants which handle or prepare fresh or frozen fish for market there is little odor if proper sanitary procedures are observed. The objectionable odor which is normally associated with handling fresh fish is usually the result of decomposition. If decomposition is prevented, all strong odors will be eliminated.

The conditions in fish-curing plants are very similar to those in plants which handle fresh fish. In these plants there should be no intense objectionable odor if proper handling procedures are used.

In fish-meal plants there are sources of odors other than from decomposition which may be objectionable. These odors may have their origin in the steam from the cooking process, in the moist gases from the dryer, in the dust from the dried fish meal, or from scorching the meal during the drying process. Although these odors are quite pronounced, they are not too objectionable if strictly fresh material is used in the plant and the plant is kept clean. The use of decomposed fish in the production of fish meal will greatly intensify the objectionable processing odors.

LOCATION OF FISH-PROCESSING PLANTS: In the United States there is no fixed pattern for plant location. In most cases fish-meal plants are located at least several miles from residential areas. The distance of the plants from residential areas depends on local atmospheric conditions, such as general wind direction, temperature, and humidity. In many instances fish-meal plants are operated in cities close to the residential districts, but usually considerable effort and equipment is required to control odors from these plants.

ODOR-CONTROL METHODS: Operators of modern fish-processing plants in the United States have recognized that one method of controlling odors is to have sufficient plant capacity to handle the fish immediately on landing rather than to accumulate the fish for later processing. This method eliminates the possibility of decomposition after the fish are delivered to the plant.

The odor which is usually associated with the handling of fish may be eliminated to a great degree by good housekeeping procedures, such as thorough washing of equipment, floors, etc., and the use of detergents and chlorine solutions. A concentration of chlorine up to 50 parts per million is used for sanitizing. Specific information on sanitizing methods, detergents, and cleaning equipment may be obtained from the various chemical companies.

A number of methods for controlling odor in fish-meal plants have been proposed and tested. Reports regarding the success of these methods differ. However, it is safe to say that the odor of fish-meal plants may be reduced or at least partially controlled by one of the following methods:

1. Use of low-temperature drying methods.
2. Use of chemical deodorants in scrubbing towers.
3. Burning of odor gases.

Recently, plants in California are reported to have been successful in reducing fish-meal processing odors by lowering the temperature in flame or steam dryers. The principal reason for lowering the temperature is to eliminate the possibility of scorching the meal during drying. Other processors have used low-temperature air-drying equipment and have reported considerable success in odor control.

Chemical deodorizing systems are claimed to be the most effective. In most cases, the chemical is brought into contact with the obnoxious gases by use of conventional scrubbing towers. Chlorine has been used for a number of years in the water of the scrubbing towers in an attempt to control odors but reports differ regarding its effectiveness. Chlorine dioxide is reported to be very effective. A rather complete description of a scrubbing tower deodorizing system using chlorine dioxide is given in an article entitled "Air-Contaminating Odors Banished by New Treatment," by E. R. Woodward and E. G. Fenrich. The article appeared in the April 1952 (vol. 24, no. 4) issue of the magazine Food Engineering.

The collection and burning of gases from plants is said to be effective in controlling odors, but references to the use of this type of equipment in fish-processing plants are not available.

The following references contain additional information on plant processes and odor control in fish-meal plants.

Drying in Fish Meal Reduction Plants, Pitt, Norman, Fish Meal and Oil Industry, vol. 3, no. 12 (November 1951), pp. 6-7, 10-11.

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